PREFACE

The following is the fourth annual progress report prepared as part of the Anadromous Fish Restoration Program Instream Flow Investigations, a 7-year effort which began in February, 1995. Title 34, Section 3406(b)(1)(B) of the Central Valley Project Improvement Act, P.L. 102-575, requires the Secretary of the Interior to determine instream flow needs for anadromous fish for all Central Valley Project controlled streams and rivers, based on recommendations of the U.S. Fish and Wildlife Service (FWS) after consultation with the California Department of Fish and Game (CDFG). The purpose of this investigation is to provide reliable scientific information to the U.S. Fish and Wildlife Service Central Valley Anadromous Fish Restoration Program to be used to develop such recommendations for Central Valley rivers.

The fieldwork described herein was conducted by Jeff Thomas, Ed Ballard, Mark Gard, Rick Williams and Jason Kent (an employee of the USGS MESC and graduate student at Colorado State University). We would particularly like to recognize Jason's assistance with our staff's fieldwork during the summer of 1998.

To those who are interested, comments and information regarding this program and the habitat resources of Central Valley rivers are welcomed. Written comments or information can be submitted to:

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INTRODUCTION

In response to substantial declines in anadromous fish populations, the Central Valley Project Improvement Act requires the doubling of the natural production of anadromous fish stocks, including the four races of chinook salmon (fall, late fall, winter, and spring), steelhead trout, and white and green sturgeon. In December 1994, the USFWS, Ecological Services, Instream Flow Assessments Branch prepared a study proposal to use the Service's Instream Flow Incremental Methodology (IFIM) to identify the instream flow requirements for anadromous fish in selected streams within the Central Valley of California. Subsequently, as discussed in our first annual report, the Sacramento, lower American and Merced Rivers were selected for study. In February 1998, the USFWS, Fish and Wildlife Office, Energy, Power and Instream Flow Assessments Branch prepared an updated study proposal (Appendix A). The studies on these rivers have been and will continue to be closely coordinated with study efforts being conducted by CDFG.

The Sacramento River study is a seven-year effort to be concluded in September, 2001. Specific goals of the study are to determine the relationship between streamflow and physical habitat availability for all life stages of chinook salmon (fall-, late fall-, winter-runs) and to identify flows at which redd dewatering and juvenile stranding conditions occur. The instream flow requirements for white and green sturgeon may also be studied; however, the inclusion of these species depends upon the availability of resources and sufficient data to enable identification of the habitats used by them. The study components include: 1) compilation and review of existing information; 2) consultation with other agencies and biologists; 3) field reconnaissance; 4) development of habitat suitability criteria (HSC); 5) study site selection and transect placement; 6) hydraulic and structural data collection; 7) construction and calibration of reliable hydraulic simulation models; 8) construction of habitat models to predict physical habitat availability over a range of river discharges; and 9) preparation of draft and final reports. The FY98 Scope of Work (SOW) identified study tasks to be undertaken. These included: field reconnaissance (study component 3); study site selection, transect placement, and hydraulic and structural data collection (study components 5 and 6); and continuing the development of HSC (study component 4).

The lower American River study was a one-year effort which culminated in a March 27, 1996 report detailing the methods and results of this effort. This report was submitted to CDFG for enclosure in their final report on the lower American River. Subsequently, questions arose as to which of the chinook salmon spawning HSC criteria used in the March 27, 1996 report would be transferable to the Lower American River. As a result, additional field work was conducted in FY97, culminating in a supplemental report submitted to CDFG on February 11, 1997. As a result of substantial changes in the Lower American River study sites from the January 1997 storms, a second round of habitat data collection and modeling was begun in April 1998. Data collection for this effort should be completed by December 1998 and a final report prepared by June 1999.

The Merced River study was a 1.5 year effort which culminated in a March 19, 1997 report detailing the methods and results of this effort. This report was submitted to CDFG for enclosure in their final report on the Merced River.

The following sections summarize project activities between October, 1997 and September, 1998.

SACRAMENTO RIVER

Field Reconnaissance and Study Site Selection

Field reconnaissance in FY98 investigated potential study sites where habitat modelling will be undertaken for chinook salmon rearing. The following section describes the methods employed and the results of FY98 reconnaissance efforts for this species.

Chinook salmon rearing habitat

During FY98, we selected one site of each mesohabitat type in each of the upstream-most three stream segments[1] (Table 1). To minimize duplication of effort, we first selected for use spawning sites. For the mesohabitat types present in each segment[2] which were not found in a spawning site, we used a random number generator to randomly select a mesohabitat unit. In January, 1998 we conducted a reconnaissance of the sites in Segments four through six to determine their viability as study sites. Each site was evaluated based on morphological and channel characteristics which facilitate the development of reliable hydraulic models. Also noted were riverbank and floodplain characteristics (e.g. steep, heavily vegetated berms or gradually sloping cobble benches) which might affect our ability to collect the necessary data to build these models. For the sites selected for modeling, the landowners along both riverbanks were identified and temporary entry permits were sent, accompanied by a cover letter, to acquire permission for entry onto their property during the course of the study.

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[1] As discussed in the FY95 annual report, we have divided the Sacramento River study area into six stream segments, based on hydrology and other factors: Colusa to Butte City (Segment 1); Deer Creek to Red Bluff Diversion Dam (Segment 2); above Lake Red Bluff to Battle Creek (Segment 3); Battle Creek to Cow Creek (Segment 4); Cow Creek to ACID (Segment 5); and ACID to Keswick (Segment 6). Segment 1 addresses green and white sturgeon, while the other segments address chinook salmon.

[2] The only mesohabitat types found in Segment 6 are Flatwater pool, Flatwater glide, run and pool. In Segment 5, there are no side channel glides, and there are no side channels in Segment 4. Off-channel areas (another mesohabitat type) were not modeled because our snorkel survey data in FY-96 indicated that they were rarely used by juvenile chinook salmon, compared to other mesohabitat types.

Table 1
Mesohabitat Units Selected for Modeling Chinook Salmon Rearing

Stream Segment	River Mile	Location	Mesohabitat Type(s)
6	298.7-298.8	Lower Lake Redding Site	Flatwater Pool
6	299-299.3	Upper Lake Redding Site	Flatwater Glide
6	300.6	Salt Creek Site	Run
5	297.7-297.8	Posse Grounds Site	Flatwater Riffle
5	296.6-296.8	Site 130	Bar Complex Pool
5	294.9-295	Site 112	Bar Complex Riffle
5	291.6-291.7	Site 96	Side Channel Run
5	298.4-298.8	Site 81	Bar Complex Glide
5	298.4-298.5	Site 80	Side Channel Pool
5	287.5-288	Site 61/63	Side Channel Riffle/Bar Complex Run
5	286.1-286.2	Site 52	Flatwater Run
5	282.7-282.8	Above Hawes Hole Site	Flatwater Glide/Flatwater Pool
4	279.8-280	Site 28	Bar Complex Pool
4	279.2-279.4	Powerline Riffle Site	Flatwater Glide
4	276.9-277.4	Site 15/17	Flatwater Pool/Flatwater Run/Flatwater Riffle
4	272.8-273	Site 9	Bar Complex Run
4	271.5-271.7	Price Riffle Site	Bar Complex Glide/Bar Complex Riffle

Transect Placement (study site setup)

Chinook salmon rearing habitat

Our original plan was to place three PHABSIM transects in each site, with the transects placed to reflect the percentage of cover on the banks at a flow of 5,000 to 15,000 cfs in the entire mesohabitat unit. As a result of high flows (over 30,000 cfs) during transect placement, we were unable to determine the cover characteristics at 5,000 to 15,000 cfs of the mesohabitat units and at transect locations. At the same time, we had successfully run the 2-D habitat modeling program funded by the U.S.G.S. office in Fort Collins, Colorado on one of our sites on the Merced River, and had found that the 2-D model accurately predicted velocities and habitat suitability of redd locations. The 2-D model uses as inputs the bed topography and cover of a site, and the water surface elevation at the bottom of the site, to predict the amount of habitat present in the site. The 2-D model avoids problems of transect placement, since the entire mesohabitat unit can be modeled, and is more efficient for modeling juvenile habitat than PHABSIM, since it allows for intensive sampling on the stream margins, where most juvenile habitat is located, and less-intensive sampling in the middle of the river, which tends to have velocities which are too high for juvenile salmon. The 2-D model also has the potential to model velocities more accurately than PHABSIM, since it uses the bed topography of the entire site, along with conservation of mass and momentum equations to change the distribution of flow across the river at different flows, rather than assuming (as PHABSIM does) that the Manning's n value at a given location does not change with flow.

Study sites were established in March and April 1998. In most cases, the study site boundaries (top and bottom) were selected to coincide with the top and bottom of the mesohabitat unit. The exceptions to the above were: 1) Salt Creek; 2) Upper Lake Redding; 3) Lower Lake Redding; 4) Posse Grounds; 5) Site 81; 6) Site 61/63; 7) Powerline; and 8) Price. The mesohabitat units that Salt Creek, Upper Lake Redding, Lower Lake Redding and Powerline were located in were extremely long (on the order of a mile), and thus it was impractical to model the entire mesohabitat unit. We decided to model 800 feet for Salt Creek and Powerline sites, since the average length of the other sites was 800 feet. Since Salt Creek only had one transect, the transect was used as the bottom of the site; it was also located a short distance (approximately 200 feet) upstream of the downstream end of the mesohabitat unit. Powerline Transect 2 was located at the dowstream end of the mesohabitat unit, and was thus used as the bottom end of this site. The two transects of the Upper Lake Redding site were selected as the top and bottom of this site to reduce the amount of additional data that needed to be collected; in addition, this resulted in a 729-foot long site (i.e. almost as long as the average length of other sites). ACID dam (the downstream boundary of this mesohabitat unit) was selected as the downstream end of the Lower Lake Redding site, while the transect at this site, located 469 feet above ACID dam, was selected as the upstream boundary of the site, again to reduce the amount of additional data that needed to be collected. Posse Grounds Transect 7 was selected as the upstream study site boundary, since it was located near the upstream boundary of the mesohabitat unit on the left bank, while Posse Grounds Transect 1 was selected as the bottom boundary to once again reduce the amount of additional data that needed to be collected. Approximately 80 percent of the mesohabitat unit that Site 81 was located in was selected for modeling for logistical reasons (so that there would be the same flow throughout the site). Mesohabitat unit 61 consisted of several channels; we only chose to model the channel which was located adjacent to (and discharged from and into) mesohabitat unit 63 to most efficiently collect data. All of mesohabitat unit 63 was included in the study site. Price Transects 2 through 5 are located in two mesohabitat units, with the mesohabitat boundary crossing the river at an extreme angle. Price Transect 2, located at the bottom end of one of the mesohabitat units, was selected as the downstream boundary of the site, while the upstream boundary of the site is at the upstream boundary of the other mesohabitat unit.

For each study site, a transect has been placed at the top and bottom of the site. The bottom transect will be modeled with PHABSIM to provide water surface elevations as an input to the 2-D model. The upstream transect will be used in calibrating the 2-D model - bed roughnesses are adjusted until the water surface elevation at the top of the site matches the water surface elevation predicted by PHABSIM. The upstream transect will also be used to determine the distribution of flow across the upstream boundary as an input to the 2-D model. For Site 61/63, an additional transect was placed in the middle of the site across the entrance to a side channel (which is not part of the site). This transect will also be modeled with PHABSIM to provide water surface elevations as an input to the 2-D model. Transect pins (headpins and tailpins) were marked on each river bank above the 30,000 cfs water surface level using rebar driven into the ground and/or lag bolts placed in tree trunks. Survey flagging was used to mark the locations of each pin.

Hydraulic and Structural Data Collection

Chinook salmon spawning habitat

During FY98 we completed the collection of hydraulic and structural data for all of the spawning sites. Specifically, water surface elevations were collected at a low flow (around 5,000 cfs) and at a very high flow (around 35,000 cfs) and substrate and dry bed data were collected on all transects. Substrate data in dry and shallow areas was determined by direct observation, while substrate in deeper areas was determined using underwater video. Water surface elevations were also measured at a high flow (around 14,000 cfs) for transects 1 through 8 at the Posse Grounds site and at two mid-range flows (8,953 and 6,844 cfs) at the Price site. Discharge was measured at a very high flow (29,855 cfs) for transects 1, 4 and 8 at the Posse Grounds site so that the flow split between the two channels at Posse Grounds transects 1 through 8 could be determined. Finally, the benchmarks for all sites above ACID and the USGS gage were tied together so that the PHABSIM WSP model could be used to simulate water surface elevations at these sites associated with different operations of ACID (i.e. boards in or out).

Chinook salmon rearing habitat

Vertical benchmarks were established at each site to serve as the reference elevation to which all elevations (streambed and water surface) will be tied. In addition, horizontal benchmarks were established at each site to serve as reference locations to which all horizontal locations (northings and eastings) will be tied. The data collected on the top and bottom transect include: 1) water surface elevations (WSELs), measured to the nearest .01 foot at three significantly different stream discharges using standard surveying techniques (differential levelling); 2) wetted streambed elevations determined by subtracting the measured depth from the surveyed WSEL at a measured flow; 3) dry ground elevations to points above bankfull discharge surveyed to the nearest 0.1 foot; 4) mean water column velocities measured at a mid-to-high-range flow at the points where bed elevations were taken; and 5) substrate and cover classification at these same locations and also where dry ground elevations were surveyed. Data collected between the transects include: 1) bed elevation; 2) northing and easting (horizontal location); 3) cover; and 4) substrate. These parameters are collected at enough points to characterize the bed topography, substrate and cover of the site. Hydraulic and structural data collection began in March 1998.

Water surface elevations have been measured at all sites at a very high flow (approximately 28,000 cfs), at a high flow (approximately 15,000 cfs) and at a mid-range flow (approximately 10,000 cfs). High flow depth and velocity measurements have been collected at all sites. In addition, for sites which do not include the entire Sacramento River flow (Sites 96, 81, 80 and 61/63), discharge measurements were collected at a mid-range flow (approximately 10,000 cfs). Depth and velocity measurements in portions of the transects with depths greater than three feet were made with the Broad-Band Acoustic Doppler Current Profiler (ADCP), while depths and velocity measurements in shallower areas were made by wading with a wading rod equipped with a Marsh-McBirney[R] model 2000 or a Price AA velocity meter.

We have used two techniques to collect the data between the top and bottom transects: 1) for areas that are dry or shallow (less than three feet), bed elevation and horizontal location of individual points are obtained with a total station, while the cover and substrate are visually assessed at each point; and 2) in portions of the site with depths greater than three feet, the ADCP is used in concert with the total station to obtain bed elevation and horizontal location. Specifically, the ADCP is run across the channel at 50 to 150-foot intervals, with the initial and final horizontal location of each run measured by the total station. A water surface elevation profile down the site is determined using the level and the electronic distance meter (used to measure the distance down the site associated with each water surface elevation measured with the level). The distance measured along each run by the ADCP, in concert with the initial and final horizontal locations, are used to compute the horizontal location (northing and easting) of each point along the run. The inital and final locations of each run are used to determine the distance down the site of each run, so that the water surface elevation of each run can be determined from the water surface elevation profile. The water surface elevation of each run is then used together with the depths from the ADCP to determine the bed elevation of each point along the run. Velocities at each point measured by the ADCP will be used to validate the 2-D model. At a later time, the initial and final locations of each run will be located using the previously-measured horizontal angle and slope distance, and marked with buoys. The underwater video and electronic distance meter will then be used to determine the substrate and cover along each run, so that substrate and cover values can be assigned to each point of the run. By determining the horizontal location of the head and tail pins of the transects at the spawning sites and collecting cover data on these transects, we can use all of the points on these transects to determine at least part of the bed topography and cover/substrate of these sites. To date, we have collected the dry and shallow data for eight sites and have collected deep bed elevation/horizontal location data for nine sites.

Hydraulic Model Contruction and Calibration

All data for the spawning sites has been compiled and checked. PHABSIM data decks have been created for Price, Hawes, Powerline and Bridge sites. Hydraulic calibration has been completed for Powerline and Bridge sites and is in progress for Price and Hawes sites. Final decks have been prepared to simulate spawning habitat for Powerline and Bridge sites, awaiting the completion of habitat suitability criteria.

Habitat Suitability Criteria (HSC) Development

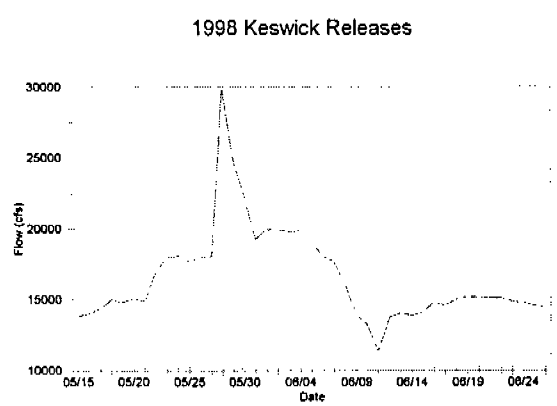
Spawning

Methods

Depth, velocity and substrate data were collected on fall-run chinook salmon redds on November 6, 7, 18 and 20, 1997. Data were collected in shallow areas on November 6, 7 and 20 by wading, while data were collected in deeper areas on November 18 using the ADCP and underwater video. Sacramento River flows (releases from Keswick Reservoir) averaged 4,492 cfs ± 10% from October 9 through November 20. Since few fall-run salmon had started constructing redds prior to October 9, these steady flow conditions ensured that the measured depths and velocities were likely the same as those present at the time of redd construction. In addition, many of the measured redds still had adult salmon holding nearby, providing further indication of recent redd construction. Fall-run spawning HSC data collection will be completed during the 1998 fall-run spawning season.

Depth, velocity and substrate data were collected on winter-run chinook salmon redds on May 26-27, June 2-3 and June 23-26, 1998. Data were collected in shallow and deep areas throughout the sampling period using the same methods described above for fall-run redds. Sacramento River flows (releases from Keswick Reservoir) varied greatly, from 11,345 to 29,899 cfs (Figure 1), from the initiation of winter-run spawning in mid-May through the end of sampling. However, we still feel confident that the depths and velocities measured were similar to those during redd construction for the following reasons: 1) most (70%) of the redds measured had fish digging or holding on the redd; 2) the 30,000 cfs flows in late May moved enough gravel to eliminate any signs of existing redds; and 3) fish were observed holding and not spawning at 20,000 cfs in early June (only one redd was found during that period); thus, it appears that most winter-run waited to spawn until the flows stabilized around 15,000 cfs in mid-June. The effort to collect spawning HSC data for the winter-run will continue for the 1999 through 2001 spawning seasons, river conditions permitting.

Figure 1



For both fall and winter-run, all of the active redds (those not covered with periphyton growth) within a given mesohabitat unit were measured. Data were collected from an area adjacent to the redd which was judged to have a similar depth and velocity as was present at the redd location prior to redd construction. This location was generally about two to four feet upstream of the pit of the redd; however it was sometimes necessary to make measurements at a 45 degree angle upstream, to the side, or behind the pit. The data were always collected within six feet of the pit of the redd. Depth was recorded to the nearest 0.1 ft and average water column velocity was recorded to the nearest 0.01 ft/s. Substrate was visually assessed for the dominant particle size range (i.e., range of 1-2"). Substrate embeddedness data were not collected because the substrate adjacent to all of the redds sampled was predominantly unembedded. The location of all redds was recorded with a Global Positioning System (GPS) unit, so that we could ensure that redds were not measured twice. All data were entered into spreadsheets for eventual analysis and development of Suitability Indices (HSC).

Due to high turbidity and widely fluctuating flows (5,831 to 55,079 cfs) from mid-January through mid-April, it was impossible to collect any late fall-run HSC data. This chinook race spawns during the peak of the winter/early spring storm season (January through mid-April) when river flows are often very high and erratic. As a result, it appears increasingly unlikely that late fall-run spawning criteria can be developed in this study. The effort to collect spawning HSC data for the late fall-run will continue for the 1999 through 2001 spawning seasons, river conditions permitting.

Results

Data were collected on a total of 96 fall-run chinook salmon redds. Seven mesohabitat units were sampled (three Flat Water (FW) Glides, one Side-Channel (SC) Riffle, one FW Run, one FW Pool and one FW Riffle). Data were collected on a total of 26 winter-run chinook salmon redds. In contrast, the aerial redd surveys found 125 winter-run redds in the areas we sampled (Jim Smith, USFWS, personal communication). Thirty seven mesohabitat units were sampled (three FW Riffles, nine FW Glides, two SC Riffles, fourteen Bar Complex (BC) Riffles, one BC Pool, three BC Glides, three FW Runs and two BC Runs). The above mesohabitat units are all of the areas where winter, fall or late-fall run redds have been observed between ACID and Battle Creek in past aerial redd surveys. However, winter-run redds were only found in three mesohabitat units (two FW Riffles and one FW Glide). All of the winter-run redds found were in the Posse Grounds or Bridge spawning study sites. Our ability to locate winter-run redds this year was limited by the 30,000 cfs flows in late May, which completely scoured periphyton off of gravel in spawning areas, and by the relatively late spawning period for winter-run this year; in most years 80% of winter-run spawn by mid-June, while this year the peak of winter run spawning was from mid-June to mid-July (Jim Smith, USFWS, personal communication). As mentioned above, no data were collected for the late fall-run.

Deep water techniques

Based on this year's experience, the underwater video/ADCP system is an efficient means of locating and collecting HSC data on chinook salmon redds in deep water, allowing a considerable area to be sampled in a short period with only a three-person crew. While it is more difficult to locate redds in deep water with the underwater video system than by wading in shallow water, our ability to locate redds has improved with experience. We have found that the easiest way to locate redds is when adult salmon are working or holding on the redd. In addition, we have found that it is much easier to locate redds when there is a substantial periphyton growth on the adjacent gravel. We were successfully able to determine if individual redds had been measured more than once using the GPS data; using the data, we concluded that we had measured one fall-run redd twice, based on the criteria that two redd measurements located two or less meters apart are measurements of the same redd. Depth, velocity and substrate values for this redd were calculated as the average of the two redd measurements.

Rearing

HSC data were collected for chinook salmon fry and juveniles (YOY) between September 16 and October 2, 1997 and on July 8-10, 1998. Starting in 1998, our intent was to sample one week every three months. However, due to high turbidity, we were unable to sample during the first six months of 1998. Data were collected during one week when Keswick releases were approximately 6,000 cfs, one week when releases were around 7,000 cfs, one week when releases were around 7,500 cfs, and one week when releases were around 15,000 cfs. Most of the effort was concentrated in areas adjacent to the bank for reasons discussed in our 1996 annual report. One person would snorkel along the bank and place a weighted, numbered tag at each location where YOY chinook salmon were observed. The snorkeler would record the tag number, the cover code[3] and the number of individuals observed in each 10-20 mm size class on a PVC wrist cuff. Cover availability in the area sampled (percentage of the area with different cover types) and the length of bank sampled (measured with the electronic distance meter) would also be recorded. Another individual would retrieve the tags, measure the depth and mean water column velocity at the tag location, and record the data for each tag number. Depth was recorded to the nearest 0.1 ft and average water column velocity was recorded to the nearest 0.01 ft/s. An adjacent mean water column velocity was also measured within two feet[4] on either side of the tag where the velocity was the highest. This measurement was taken to eventually provide the

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[3] If there was no cover elements (as defined in Table 2) within one foot horizontally of the fish location, the cover code was 0 (no cover).

[4] Two feet was selected based on a mechanism of turbulent mixing transporting invertebrate drift from fast-water areas to adjacent slow-water areas where fry and juvenile salmon reside, taking into account that the size of turbulent eddies is approximately one-half of the mean river depth (Terry Waddle, USGS, personal communication), and assuming that the mean depth of the Sacramento River is around four feet (ie., four feet x ½ = two feet).

Table 2
Cover Coding System

Cover Category	Cover Code[5]
no cover	0
cobble	1
boulder	2
fine woody vegetation (< 1" diameter)	3
branches	4
log (> 1' diameter)	5
depth (> 3' from surface)	6
overhead cover (< 2' from water surface)	7
undercut bank	8
aquatic vegetation	9
rip-rap	10

option of using an alternative habitat model which considers adjacent velocities in assessing habitat quality. Adjacent velocity can be an important habitat variable as fish, particularly fry and juveniles, frequently reside in slow-water habitats adjacent to faster water where invertebrate drift is conveyed. Both the residence and adjacent velocity variables are important for fish to minimize the energy expenditure/food intake ratio and maintain growth. Data taken by the snorkeler and the measurer were correlated at each tag location and entered into a spreadsheet for eventual analysis and development of HSC. All YOY chinook salmon observed have been classified by race according to a table provided by CDFG correlating race with life stage periodicity and total length. Data were also compiled on the length of each mesohabitat and cover type sampled to ensure that equal effort would eventually be spent in each type and that each location was only sampled once at the same flow (to avoid problems with pseudo-replication). We will continue to sample one week every three months over the next two years with increased effort to sample in mid-channel areas where YOY salmon have been observed in previous years by other investigators (Keith Marine, personal communication).

[5] In addition to these cover codes, we have been using composite cover codes; for example, 4/7 would be branches plus overhead cover.

Results

To date, we have taken 534 measurements (depth and velocity) where YOY chinook salmon were observed. All of these measurements were made near the river banks. There were 340 observations of fish less than 40 mm, 410 observations of 40-60 mm fish, 76 observations of 60-80 mm fish and 19 observations of fish greater than 80 mm[6]. According to the race classification table, these numbers account for 233 fall-run, 248 late fall-run and 170 winter-run YOY chinook salmon. A total of 9.1 miles of near-bank habitat and 1.9 miles of mid-channel habitat have been sampled to date. Table 3 summarizes the number of feet of different mesohabitat sampled to date and Table 4 summarizes the number of feet of different cover types sampled to date.

Table 3
Distances (feet) Sampled for Juvenile Chinook Salmon HSC Data - Mesohabitat Types

Mesohabitat Type	Near-bank habitat distance sampled	Mid-channel habitat distance sampled
Bar Complex Glide	4831	3610
Bar Complex Pool	3040	900
Bar Complex Riffle	5862	1230
Bar Complex Run	5046	1275
Flatwater Glide	5966	770
Flatwater Pool	2100	0
Flatwater Riffle	4339	1200
Flatwater Run	5362	900
Off-Channel Area	900	0
Side-Channel Riffle	7995	270
Side-Channel Run	2855	0

[6] These numbers total much more than 534 because most of the observations included YOY of several size classes and only one measurement was made per group of closely associated individuals.

Table 4
Distances (feet) Sampled for Juvenile Chinook Salmon HSC Data - Cover Types

Cover Type	Near-bank habitat distance sampled	Mid-channel habitat distance sampled
None	9845	513
Cobble	13452	6280
Boulder	2744	263
Fine Woody	6421	0
Branches	8527	200
Log	1358	0
Depth	0	2900
Overhead	1206	0
Undercut	1397	0
Aquatic Vegetation	1259	0
Rip Rap	686	0
Overhead + instream	10791	0

Cover Code Analysis

We conducted an analysis of our snorkel survey data (discussed in our 1996 annual report) to determine if the cover codes could be simplified. Specifically, we used Pearson's test for association (chi-squared test) to determine if there were statistically significant differences between cover codes for juvenile chinook salmon presence versus absence. The statistical tests are presented in Tables 5 and 6. For Table 5, an asterisk indicates that presence/absence of fish for those cover codes were significant different at $p = 0.05$. For Table 6, an asterisk indicates that fish presence/absence for the cover codes in Group A were significantly different than fish presence/absence for the cover codes in Group B at $p = 0.05$. Our analysis indicated that there are two distinct groups of cover types; cover types within the groups were not significantly different in fish presence versus absence, while the two groups were significantly different from each other in fish presence versus absence. The first cover group (cover group code 0) included cover codes 0, 1, 2, 3, 5, 8, 9 and 10. The other cover group (cover group code 1) included cover codes 3/7, 4/7, 5/7, 9/7, 4 and 7. We could not include cover code 6 in the analysis because we did not have enough observations of this cover code. Since we have not yet had any observations of fish using cover code 6, we are considering eliminating this cover code. To date, we have sampled 34,376 feet of near-bank habitat and 9,955 feet of mid-channel habitat with cover group 0, but only 13,920 feet of near-bank habitat and 200 feet of mid-channel habitat with cover group 1 for our juvenile HSI criteria development. Accordingly, we plan to intensify our sampling in cover group 1 habitat in the next two years to even out the sampling of these two cover groups.

Table 5
Statistical Tests of Differences Between Cover Codes

Cover Codes	c-value
3/7, 4/7, 5/7, 9/7, 4, 7	6.68
0, 1, 2, 3, 5, 8, 9, 10	8.52
3/7, 4/7, 5/7, 9/7, 4, 7, 0, 1, 2, 3, 5, 8, 9, 10	237.9 *

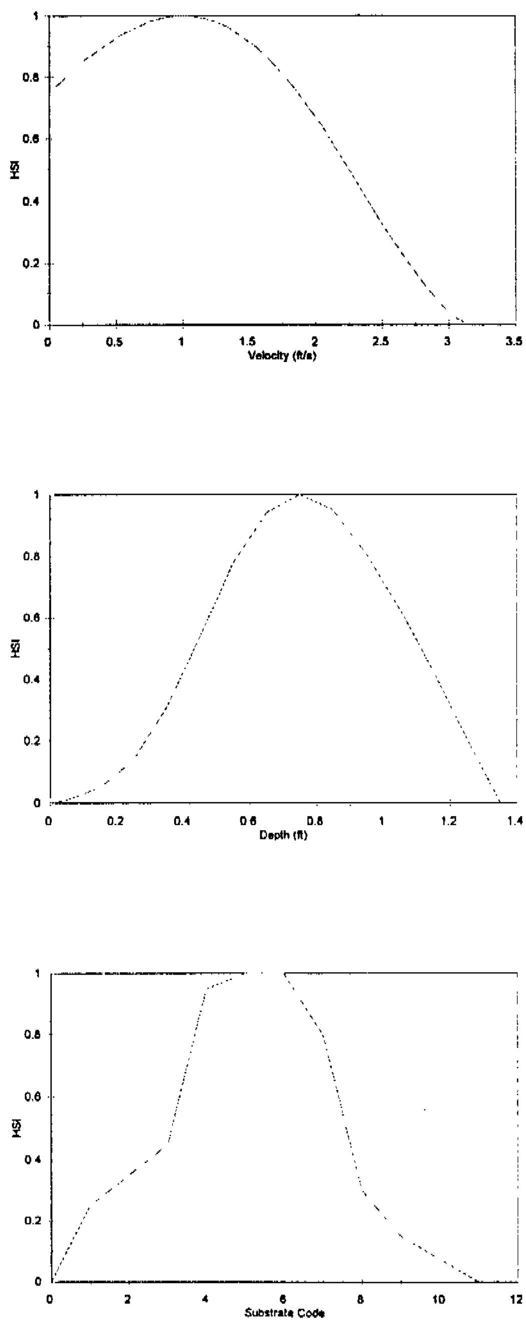
Table 6
Statistical Tests of Differences Between Cover Code Groups

Cover Codes in Group A	Cover Codes in Group B	c-value
3/7, 4/7, 5/7, 9/7	7	3.37
3/7, 4/7, 5/7, 9/7	4	1.25
3/7, 4/7, 5/7, 9/7, 4, 7	0, 1, 2, 3, 5, 8, 9, 10	221.9 *
0, 1, 2, 3, 9, 10	5	2.55
0, 1, 2, 3, 9, 10	8	2.84

Macroinvertebrate Criteria

We have embarked on developing a second set of juvenile chinook salmon HSI criteria - one based on food supply rather than physical habitat. Specifically, we will be developing HSI criteria for macroinvertebrate biomass and diversity. As an example, HSI criteria for macroinvertebrate diversity developed by James Gore of Columbus State University are presented in Figure 2. The criteria we develop will be run on the juvenile rearing site habitat models to predict the relationship between flow and macroinvertebrate biomass and diversity. During FY98, we purchased a net and began construction of a macroinvertebrate sampler to use in this effort. The sampler will be used to collect macroinvertebrates from a 9-square-foot area. The sampler is four feet high, so it can be used to sample areas with depths up to four feet. The sampler will require three individuals - two to hold the sampler in place, and the third individual to clean off rocks within the 9-square-foot area, with the current carrying the macroinvertebrates into the net. The net will be detachable, so that the macroinvertebrates in the net can be washed into the cod end of the net and then transferred to a jar with 70% alcohol for transport back to the lab for analysis. We plan to stratify our sampling by season, depth, velocity and substrate. Specifically, samples will be collected once every three months, with one sample collected in each combination of 1-foot increments of depth (up to 4 feet), 1-foot/sec increments of velocity

Figure 2
Macroinvertebrate Diversity Criteria[7]



[7] Developed by James Gore, Columbus State University. Substrate codes are as follows: 1 = fines, 2 = small gravel, 3 = medium gravel, 4 = large gravel, 5 = small cobble, 6 = medium cobble, 7 = large cobble, 8 = small boulder, large boulder, 10= bedrock, 11 = upland vegetation.

(up to 4 feet/sec) and four ranges of substrate size. Before a sample is collected, the depth and mean column velocity at the sampling site will be measured and the substrate size noted. We expect that all sampling will be completed during FY99.

LOWER AMERICAN RIVER

As a result of the 115,000 cfs flood releases made into the lower American River in January of 1997, considerable morphological changes have occurred in many areas of the river including some of our study sites. As a result, CDFG inquired into the possibility that we collect additional hydraulic and structural data, and develop new spawning habitat models for fall-run chinook salmon on the lower American River.

Field Reconnaissance and Study Site Selection

We selected five sites (Table 7) based on CDFG aerial photos of fall 1997 chinook salmon redds in the Lower American River. Sites chosen had the highest concentration of redds. Each site was evaluated based on morphological and channel characteristics which facilitate the development of reliable hydraulic models. Also noted were riverbank and floodplain characteristics (e.g. steep, heavily vegetated berms or gradually sloping cobble benches) which might affect our ability to collect the necessary data to build these models. We obtained an extension of our original temporary encroachment permit from the Sacramento County Department of Parks and Recreation to allow field work to continue through December 31, 1998.

Table 7
Sites Selected for Modeling Chinook Salmon Spawning

Site Name	Number of Transects
Sailor Bar	4
Above Sunrise	7
Sunrise	7
El Manto	2
Rossmoor	7

Transect Placement (study site setup)

A total of 27 transects were placed in the established study sites in April 1998. At each site, transects were located to cross the areas most heavily used by spawning fall-run chinook salmon in 1997 (as identified on CDFG aerial photographs). Transect pins (headpins and tailpins) were marked on each river bank above the 12,000 cfs water surface level using rebar driven into the ground and/or lag bolts placed in stumps. Survey flagging was used to mark the locations of each pin.

We also decided to run the 2-D habitat modeling program funded by the U.S.G.S. office in Fort Collins, Colorado to allow for additional comparisons of the 2-D model to PHABSIM. The 2-D model uses as inputs the bed topography and substrate of a site, and the water surface elevation at the bottom of the site, to predict the amount of habitat present in the site. The 2-D model will be run for each of the five study sites. The downstream-most PHABSIM transect will used as the bottom of the site, to provide water surface elevations as an input to the 2-D model. The upstream-most PHABSIM transect will be used as the top of the site, to calibrate the 2-D model - bed roughnesses are adjusted until the water surface elevation at the top of the site matches the water surface elevation predicted by PHABSIM. This transect will also be used to determine the distribution of flow across the upstream boundary as an input to the 2-D model.

Hydraulic and Structural Data Collection

Vertical benchmarks were established at each site to serve as the reference elevation to which all elevations (streambed and water surface) will be tied. In addition, horizontal benchmarks were established at each site to serve as reference locations to which all horizontal locations (northings and eastings) will be tied.

The data collected at each PHABSIM transect include: 1) water surface elevations (WSELs), measured to the nearest .01 foot at a minimum of three significantly different stream discharges using standard surveying techniques (differential levelling); 2) wetted streambed elevations determined by subtracting the measured depth from the surveyed WSEL at a measured flow; 3) dry ground elevations to points above bankfull discharge surveyed to the nearest 0.1 foot; 4) mean water column velocities measured at a mid-to-high-range flow at the points where bed elevations were taken; and 5) substrate classification at these same locations and also where dry ground elevations were surveyed. Data collected for the 2-D model include: 1) bed elevation; 2) northing and easting (horizontal location); and 3) substrate. These parameters are collected at enough points to characterize the bed topography and substrate of the site. Hydraulic and structural data collection began in April 1998.

Water surface elevations have been measured at all sites at five flows (approximately 1000, 2000, 4000, 7500 and 11,000 cfs). Discharges were also measured at a number of these flows for split-channel transects. Depth and velocity measurements in portions of the transects with depths greater than three feet were made with the ADCP, while depths and velocity measurements in shallower areas were made by wading with a wading rod equipped with a Marsh-McBirney[R] model 2000 or a Price AA velocity meter. In addition, substrate data has been collected for almost all transects. Substrate data in dry and shallow areas was determined by direct observation, while substrate in deeper areas was determined using underwater video. Velocity sets and an additional set of water surface elevations will be collected in October 1998 at a flow of approximately 2500 cfs.

We have used two techniques to collect the data for the 2-D model: 1) for areas that are dry or shallow (less than three feet), bed elevation and horizontal location of individual points are obtained with a total station, while the substrate is visually assessed at each point; and 2) in portions of the site with depths greater than three feet, the ADCP is used in concert with the total station to obtain bed elevation and horizontal location. Specifically, the ADCP is run across the channel at 50 to 150-foot intervals, with the initial and final horizontal location of each run measured by the total station. A water surface elevation profile down the site is determined using the level and the electronic distance meter (used to measure the distance down the site associated with each water surface elevation measured with the level). The distance measured along each run by the ADCP, in concert with the initial and final horizontal locations, are used to compute the horizontal location (northing and easting) of each point along the run. The inital and final locations of each run are used to determine the distance down the site of each run, so that the water surface elevation of each run can be determined from the water surface elevation profile. The water surface elevation of each run is then used together with the depths from the ADCP to determine the bed elevation of each point along the run. Velocities at each point measured by the ADCP will be used to validate the 2-D model. At a later time, the initial and final locations of each run are located using the previously-measured horizontal angle and slope distance, and marked with buoys. The underwater video and electronic distance meter are then used to determine the substrate along each run, so that substrate values can be assigned to each point of the run. By determining the horizontal location of the head and tail pins of all of the PHABSIM transects, we can use all of the points on these transects to determine at least part of the bed topography and substrate of these sites. To date, we have collected the dry and shallow data for portions of three sites and have completed collecting deep bed elevation/horizontal location data for all five sites. In addition, we have collected the substrate data for the deep bed locations for two sites. Field data collection should be completed by the end of December 1998.

SACRAMENTO RIVER TRIBUTARIES

As a result of discussions on our February 1988 revised study proposal (Appendix A), an additional task was added to the FY98 scope of work: preparation of a report summarizing and evaluating existing instream flow studies on the following Sacramento River tributaries: Deer Creek, Mill Creek, Butte Creek, Bear River, Cow Creek, and Antelope Creek. A draft report (Appendix B) was submitted on August 17, 1998 to Anadromous Fish Restoration Program and other resource agency staff.

SALMOD

Jason Kent, a graduate student at Colorado State University, will be applying the SALMOD salmon production model to the Sacramento River for his master's thesis. SALMOD will integrate the results of our Sacramento River instream flow studies and the instream flow studies currently being conducted by CDFG to link Keswick release flow rates and water temperatures with chinook salmon production in the Sacramento River. As a result, it will be possible to directly assess the effects of different Keswick release schedules on pre-smolt chinook salmon production.

APPENDIX A

REVISED STUDY PROPOSAL

REVISED STUDY PROPOSAL

IDENTIFICATION OF THE INSTREAM FLOW REQUIREMENTS FOR ANADROMOUS FISH IN THE STREAMS WITHIN THE CENTRAL VALLEY OF CALIFORNIA

Prepared for

U.S. FISH AND WILDLIFE SERVICE
CENTRAL VALLEY ANADROMOUS FISH RESTORATION PROGRAM

Prepared by

U.S. FISH AND WILDLIFE SERVICE
ECOLOGICAL SERVICES
INSTREAM FLOW ASSESSMENTS BRANCH
SACRAMENTO FIELD OFFICE

FEBRUARY 1998

INTRODUCTION

The Instream Flow Assessment Branch prepared an initial Draft Study Proposal dated October 31, 1994 which proposed instream flow investigations on six Central Valley streams (Sacramento River, Cow Creek, Antelope Creek, Deer Creek, Butte Creek and Bear River). After meetings with managers and staff of the Central Valley Anadromous Fish Restoration Program (Program) and the California Department of Fish and Game (CDFG), Streamflow and Habitat Evaluation Program, the Instream Flow Assessment Branch's proposal was amended in a final Draft Study Proposal, dated December 15, 1994, to revise the scope of study to five streams (Sacramento, American, Merced and Bear Rivers and Butte Creek) over a five-year period (from October 1994 through September 1999). The above five streams were chosen because they historically had healthy anadromous fisheries; the declining status of their anadromous resources is largely due to insufficient streamflows; available information on which reliable instream flow recommendations can be made is incomplete; and because Program managers consider them a high priority. For the Sacramento River, the Anadromous Fish Restoration Program Working Paper (May 9, 1995) identified completing an integrated instream flow study to refine a river regulation program as one of the actions needed to restore Sacramento River chinook salmon populations (page 1-IV-3, item 5). This item was carried through into the December 6, 1995 draft Anadromous Fish Restoration Plan (page 31, evaluation item 1), and was identified therein as a high priority. The investigations proposed in the final Draft Study Proposal were part of a coordinated effort on the part of the FWS and CDFG to provide reliable scientific information to Program managers regarding the instream flow requirements of anadromous fish populations inhabiting streams within the Central Valley of California.

METHODS

To develop a flow regime which will accommodate the habitat needs of anadromous species inhabiting streams it is necessary to determine the relationship between streamflow and habitat availability for each life stage of those species. We are using the models and techniques contained within the Instream Flow Incremental Methodology (IFIM) to establish these relationships. The IFIM is a habitat-based tool developed by the USFWS to assess instream flow problems. The Methodology represents the current state of the art for evaluating the impacts which alternative flow regimes have on riverine habitat. It is widely accepted and has been extensively used worldwide to resolve water allocation conflicts and predict project impacts.

The decision variable generated by the IFIM is total habitat area for each life stage of each evaluation species (or race as applied to chinook salmon). Habitat incorporates both macro- and microhabitat features. Macrohabitat features include longitudinal changes in channel characteristics, base flow, water quality, and water temperature. Microhabitat features include the hydraulic and structural conditions which define the actual living space of the organisms. The total habitat available to a species/life stage at any streamflow is the area of overlap between available microhabitat and suitable macrohabitat conditions.

The Physical Habitat Simulation (PHABSIM) component of the IFIM is a collection of computer models designed to quantify the amount of habitat available for different life stages of evaluation species over a range of streamflows. PHABSIM will produce results based on all of the macro- and microhabitat features listed above except water quality and temperature. These features must be incorporated into the total habitat model separately. The key components of PHABSIM are predictive hydraulic models, habitat suitability index (HSI) criteria, and habitat models. A reliable hydraulic model is first developed from measurements taken on established transects at several different streamflows. The habitat model uses the output from the hydraulic models combined with reliable HSI to compute a predictive relationship between physical habitat availability and streamflow. HSI translate hydraulic and structural elements of streams into indices of habitat quality. HSI are the biological input into PHABSIM and describe the hydraulic and structural conditions (i.e., depths, velocities, substrate, cover) a species/life stage uses.

The use of accurate and dependable HSI criteria is extremely important to the validity of the habitat model results. HSI criteria are developed from measurements taken where fish are observed residing in a stream. The most effective method for developing such criteria is through direct underwater observation (snorkeling and/or SCUBA). Care must be taken when collecting observational data to insure that observed fish were able to select preferred habitat conditions from a wide range of available conditions. Observations should not be collected in streams with extremely degraded habitats or under extreme conditions (e.g., very low flows). HSI criteria should describe the behavior of animals with respect to the microhabitat conditions they freely select, not conditions which are used when choice is limited. The use of an equal effort sampling design addresses this issue. Collection of spawning HSI criteria requires that flows be relatively constant from the initiation of spawning through the date of data collection, so that the depths and velocities during redd construction are the same as when observations are made. As a result, flows need to be relatively constant during early October to late November for fall-run spawning HSI data, during mid January to early March for late-fall run spawning HSI data, and during mid May to mid June for winter-run spawning HSI data.

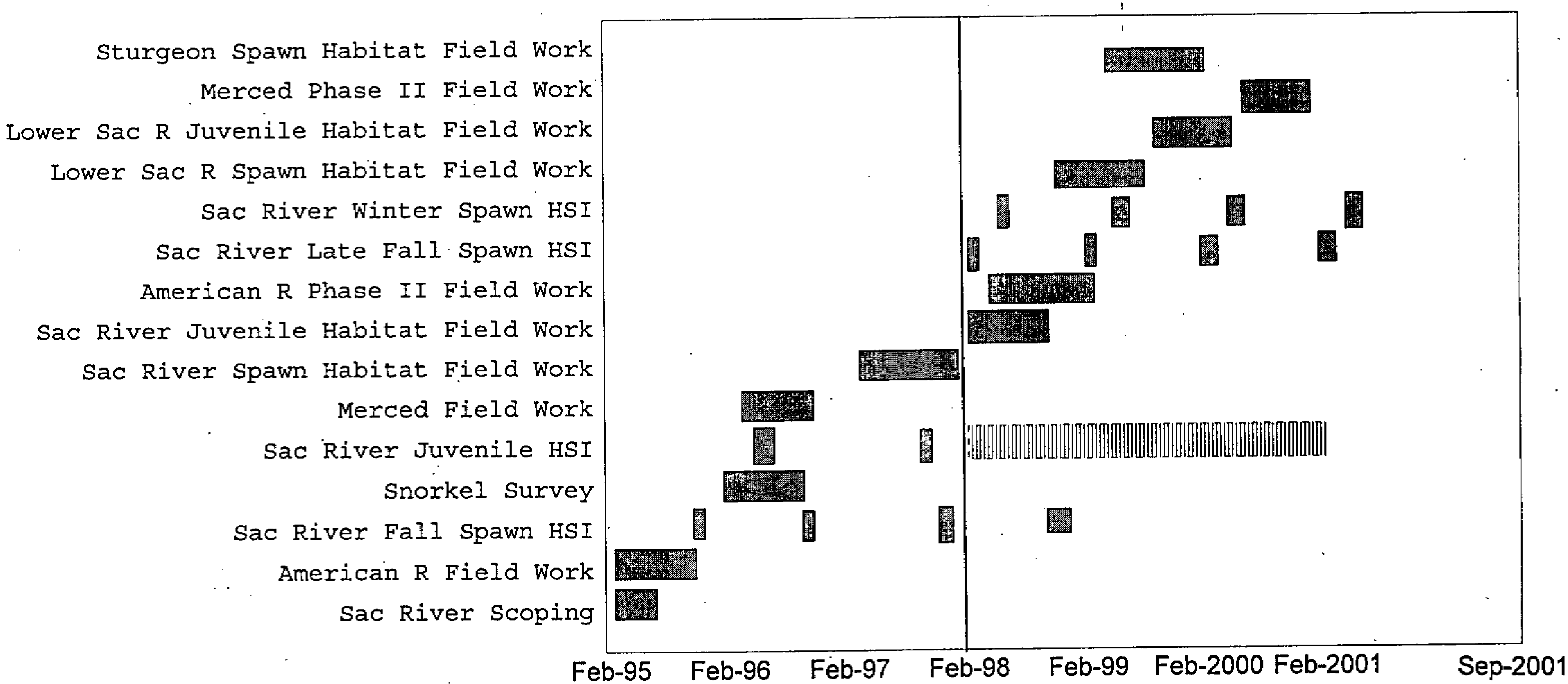
Flow-related passage conditions for migrating adults and/or juveniles can be addressed through the use of the hydraulic models within PHABSIM. The relationship between stream water temperatures and flow is developed by a model. The Service's SNTEMP temperature model is a data intensive model which produces reliable results. Model results are integrated with habitat model results to determine total habitat availability.

PROJECT PROGRESS

Details of the first three years of project progress are contained in the Instream Flow Assessment Branch's annual reports. Due to the time needed to get funding in place, the Instream Flow Assessment Branch's activities on this project did not start until February 1995, and CDFG's activities did not start until July 1995. Habitat modeling of American River chinook salmon and steelhead spawning, and scoping on the Sacramento River instream flow investigation started in February 1995 (Figure 1). In addition, a dephi analysis was begun in June 1995 and completed in February 1996 to develop Sacramento River white sturgeon spawning criteria. A final report on the American River habitat modeling, using HSI curves developed from data collected by CDFG on the American River and HSI curves from other rivers, was released in March 1996. Sacramento River scoping activities were completed by June 1995. It became clear from the Sacramento River scoping that additional effort would be needed on the Sacramento River, beyond that envisioned in the December proposal. As a result, activities on Bear River and Butte Creek were eliminated from the scope of work to allow additional effort to be spent on the Sacramento River. The proposed removal of a number of diversions from Butte Creek also made instream flow activities there premature until final action was taken on those diversions.

The Instream Flow Assessment Branch's planned effort on this project was cut in half for the period of July 1995 through January 1996, due to the unforeseen need to assist in the completion of the Trinity River Flow Evaluation, a high priority for the Sacramento Field Office. As a result, the initiation of fieldwork on the Sacramento River, except for collection of fall-run chinook salmon spawning HSI data, was delayed until January 1996.

FIGURE 1



Sturgeon Spawn Habitat Field Work
Merced Phase II Field Work
Lower Sac R Juvenile Habitat Field Work
Lower Sac R Spawn Habitat Field Work
Sac River Winter Spawn HSI
Sac River Late Fall Spawn HSI
American R Phase II Field Work
Sac River Juvenile Habitat Field Work
Sac River Spawn Habitat Field Work
Merced Field Work
Sac River Juvenile HSI
Snorkel Survey
Sac River Fall Spawn HSI
American R Field Work
Sac River Scoping
Feb-95
Feb-96
Feb-97
Feb-98
Feb-99
Feb-2000
Feb-2001
Sep-2001

The Instream Flow Assessment Branch started the next major field activity on the Sacramento River, snorkel surveys to assess the relative abundance of juvenile chinook salmon in different mesohabitat types, in January 1996. The snorkel survey data were needed to determine which mesohabitat types should be selected for modeling chinook salmon juvenile habitat, and were also provided to CDFG as part of our coordination with their instream flow efforts. Unfortunately, high Sacramento River flows and turbidity delayed all but initial efforts on the snorkel survey until late March 1996, as well as precluding any collection of late-fall chinook salmon spawning HSI data. The Instream Flow Assessment Branch's snorkel survey activities were completed in September 1996, when CDFG began their snorkel survey efforts. Collection of juvenile chinook salmon HSI data was conducted concurrent to the snorkel survey activities during the period of April through June 1996. Juvenile chinook salmon HSI data were also collected in August and September 1997.

Modeling of Merced River fall-run chinook salmon habitat, as well as the development of site-specific Merced River fall-run chinook salmon spawning HSI criteria, was started in March 1996 and completed by March 1997. Data for site-specific fall-run chinook salmon spawning HSI criteria were also collected on the American River in the fall of 1996, resulting in a February 1997 supplemental report on fall-run chinook salmon spawning habitat in the American River. However, as a result of significant channel changes caused by the January 1997 storms, the habitat-flow relationships developed for these two rivers may no longer be valid.

Flow fluctuations during mid-May through mid-June 1996 precluded collection of shallow winter-run spawning HSI data. In early June 1996, an effort was made using SCUBA divers towed by a jet boat to locate winter-run redds in deep (>6') water; only one winter-run redd was located in three days of effort. As a result, Instream Flow Assessment Branch staff investigated and acquired underwater video equipment to locate redds in deep water to allow more area to be covered than using SCUBA divers. As a result of the January 1997 storms, the Sacramento River was extremely turbid from January through August 1997, precluding the collection of late-fall or winter run spawning HSI data in

1997, or juvenile HSI data from January through August 1997. The underwater video technology was successfully used in the fall of 1997 to locate 25 fall-run redds in deep water. Flow fluctuations this winter will also preclude collection of late-fall spawning HSI data in 1998.

Field work for modeling chinook salmon spawning habitat in the Sacramento River between Keswick Dam and Battle Creek began in March of 1997 and is nearly complete. The Instream Flow Assessment Branch purchased an Acoustic Doppler Current Profiler (ADCP) in September 1995. We used the ADCP extensively to measure depths and velocities across the transects. As a result, we were able to carry out all of the fieldwork for this modeling with a three-person crew in less than one day per transect. While this modeling effort will include 83% of winter and late-fall spawning, it only includes 47% of the fall-run spawning area; another 38% of Sacramento River fall-run chinook salmon spawn between Battle Creek and Deer Creek. Field work began in January 1998 to collect juvenile chinook salmon rearing habitat modeling data in the Sacramento River between Keswick Dam and Battle Creek.

ACCOMPLISHMENTS POSSIBLE DURING THE ORIGINAL PROJECT PERIOD

If the project period is not extended beyond September 1999, we would be able to complete: 1) habitat modeling of chinook salmon spawning and rearing in the Sacramento River between Keswick Dam and Battle Creek, including juvenile stranding; 2) modeling of post-January-1997-flood American River chinook salmon spawning habitat; 3) development of Sacramento River fall-run chinook salmon spawning HSI criteria; and 4) development of Sacramento River fry chinook salmon rearing HSI criteria. Thusfar, we have collected 375 observations of Sacramento River fall-run chinook salmon redds and 456 observations of Sacramento River juvenile chinook salmon. However, most of the observations of juvenile chinook salmon have been of fry (less than 50 or 60 mm FL). It is not likely that enough observations could be made of larger juvenile chinook salmon within the original project period to develop separate criteria for them. Typically, there are significant differences in habitat usage for fry versus larger juvenile chinook salmon, and thus separate HSI criteria should be developed for each. Habitat modeling fieldwork would need to be completed by January 1999 and HSI field work would need to be completed by June 1999 to allow final reports to be completed by September 1999.

PROPOSED ADDITIONAL WORK

We are proposing to extend the original project period for an additional two years, through September 2001. Habitat modeling field work would be completed by January 2001 and HSI field work would be completed by June 2001. Final reports would be submitted by September 2001. We would prepare a report in FY 98 reviewing the available instream flow studies and identifying what additional instream flow studies were needed for the following streams: 1) Deer Creek; 2) Mill Creek; 3) Butte Creek; 4) Bear River; 5) Cow Creek; and 6) Antelope Creek. We would then consult with Program and other resource agency staff to prioritize work for FY 99 through FY 2001 for the following potential additional work: 1) habitat modeling of chinook salmon spawning in the Sacramento River between Battle Creek and Deer Creek; 2) habitat modeling of chinook salmon rearing in the Sacramento River between Battle Creek and Deer Creek, including juvenile stranding; 3) development of a water temperature model and modeling of steelhead spawning and rearing habitat in the Bear River; 4) modeling of Sacramento River white sturgeon spawning habitat; 5) modeling of post-January-1997-flood Merced River chinook salmon habitat; 6) habitat and temperature modeling of instream flow requirements for anadromous salmonids in Cow Creek and its tributaries; 7) modeling of upstream and downstream passage of anadromous salmonids and temperature modeling in Antelope Creek; 8) modeling of passage flows, water temperature and instream flows for fall-run chinook salmon rearing and spawning in Deer Creek; 9) modeling of passage flows, water temperature and instream flows for anadromous salmonid rearing and spawning in Butte Creek; and 10) modeling of passage flows, water temperature and instream flows for fall-run chinook salmon rearing and spawning in Mill Creek. Available time will limit the number of the above activities which could actually be accomplished during

FY 99 to 2001. In addition, independent of the priority-setting process, we would accomplish the following additional work during FY 99 through FY 2001: 1) development of Sacramento River late-fall and winter-run chinook salmon spawning HSI criteria; and 2) development of Sacramento River juvenile (ie > 50-60 mm FL) chinook salmon rearing HSI criteria. It is likely that flow conditions will allow for development of winter-run chinook salmon spawning criteria, but flow conditions may still not allow for development of late-fall run chinook salmon spawning criteria, even with an extension of the project period.

Products

For the American River, instream flow modeling results will be submitted to CDFG for inclusion in their final report for this river. For the remaining streams, a final report will be submitted describing all aspects of the investigations conducted and detailing the study results. These reports will be complete and scientifically defensible. Annual status reports will be submitted on September 30 of each year.

Schedule

The investigations would continue over the course of the next three and a half years through FY 2001. Final reports will be submitted as they are completed. Estimated schedules for the Sacramento, American and Merced Rivers are shown in Figure 1, but may be revised based on the prioritization process. Estimated schedules for other rivers will be developed by the beginning of FY 99, based on the results of the prioritization process.

SACRAMENTO RIVER

Our proposed investigations on the Sacramento River will continue through

September 2001. Due to the magnitude of this effort, all components of this study will continue to be conducted jointly with CDFG. Modeling of white sturgeon habitat would be an abbreviated effort, with four transects each at four sites between Colusa and Butte City where sampling by CDFG has confirmed white sturgeon spawning activity.

Modeling of juvenile chinook salmon stranding would also be an abbreviated effort. The first step would be to look for isolated areas of water just after ramping down of flows and identify where the last connection with the Sacramento River was for each isolated pool. We would then collect water surface elevations at three flows in the Sacramento River at each connection point, along with determining the maximum depth at those locations, to develop log-log relationships between flow and river stage. These relationships would be used, along with surveys of the bed elevation at the low point of the connection, to determine the flow at which each area of water becomes isolated from the Sacramento River. We would then estimate the area of each isolated pool from aerial photographs or Global Positioning System measurements to develop a relationship between increments of flow drop and area of stranding habitat. This effort would be conducted during the same period of time as the modeling of juvenile chinook salmon rearing habitat, when ramping down of Sacramento River flows occur.

AMERICAN RIVER

CDFG studies on the American River are in various phases of completion. The Department has requested our assistance in developing the relationship between streamflow and spawning habitat availability following the January 1997 floods. We will establish study sites in several riffle habitats where fall-run chinook salmon and steelhead are known to spawn, collect hydraulic and structural data along transects placed in these sites, and model them. Model results will be given to CDFG for use in determining the instream flow requirements for these species. CDFG will submit the final report for the American River.

MERCED RIVER

CDFG Region 2 has requested our assistance in developing the relationship between streamflow and spawning habitat availability following the January 1997 floods. Field work would not be able to start until after the fall of 1999, when three years of post-January-1997-flood redd count data are available to use in selecting study sites. We would establish study sites in several riffle habitats where fall-run chinook salmon are known to spawn, collect hydraulic and structural data along transects placed in these sites, and model them.

BEAR RIVER

A previous study on the Bear River established the relationship between streamflow and microhabitat availability for fall-run chinook salmon. We would propose to use the hydraulic modeling decks from that study with existing steelhead trout HSI criteria from other rivers to establish the relationship between streamflow and microhabitat availability for steelhead as well. If time permits, we would conduct transferability tests to ensure that steelhead criteria from other rivers will transfer to the Bear River. This analysis would include the development of a temperature model, missing from the previous investigation. The model results would be integrated with the results from both instream flow studies to determine the streamflow requirements for both species.

COW CREEK

On Cow Creek and its tributaries we would determine the instream flow requirements for fall- and late fall-run chinook salmon. The flow requirements for steelhead trout would be determined in South Cow, Old Cow, and North Cow Creeks. Habitat models and a temperature model would both be developed.

ANTELOPE CREEK

Work on Antelope Creek would focus on the identified passage problems for adult and juvenile anadromous salmonids. We would determine the streamflows necessary for these fish to successfully negotiate the reach below the two major diversions at the canyon mouth; and determine the relationship between streamflow and water temperature between the diversions and the Sacramento River.

DEER CREEK

Work on Deer Creek would include passage flows, water temperature, and the relationship between instream flow and fall-run chinook spawning and rearing habitat. Streamflows which would allow access to spawning and rearing habitats for spring-run chinook and steelhead would be determined. These habitats are located above diversions in the valley floor and are reported to be relatively unaltered. Fall-run chinook salmon spawn below the diversions. The instream flow requirements for this population would be determined. A temperature model would also be developed below the diversions.

BUTTE CREEK

Work on Butte Creek would be to determine the relationship between instream flow and habitat availability for fall-run chinook salmon spawning and rearing between the upper two diversion dams where most of this population is known to reproduce; and in the reach between the upper-most diversion dam and the Centerville Head Dam for spring-run chinook salmon and steelhead. We would also determine the flows necessary for adult passage between the diversion dams located on Butte Creek. A temperature model would be developed for the stream.

MILL CREEK

Work on Mill Creek would include passage flows, water temperature, and the relationship between instream flow and fall-run chinook spawning and rearing habitat. Streamflows which would allow access to spawning and rearing habitats for spring-run chinook and steelhead would be determined. These habitats are located above diversions in the valley floor and are reported to be relatively unaltered. Fall-run chinook salmon spawn below the diversions. The instream flow requirements for this population would be determined. A temperature model would also be developed below the diversions.

EFFORT

Activity	Biologist Days FY99-2001
Total Available Biologist Days	2000
Sacramento River Juvenile HSI criteria	130
Sacramento River Spawning HSI criteria	90
Modeling and Report Preparation	400
Total Remaining Biologist Days	1380
Sacramento River (Battle-Deer) Spawning Habitat	300
Sacramento River (Battle-Deer) Rearing Habitat	600
Sacramento River (Deer-Feather) Rearing Habitat	600
Sturgeon Spawning Habitat	160
Redo Merced River Spawning Habitat	220
Bear River	100
Cow Creek	320
Antelope Creek	160
Deer Creek	200
Butte Creek	240
Mill Creek	200

BUDGET

As shown below, if the project period is extended until September 2001, the total cost of the project will not exceed the total originally budgeted amount.

Fiscal Year	Original Budget	Revised Budget
1995	$250,000	$114,000 [1]
1996	$350,000	$210,000 [1]
1997	$400,000	$277,000 [1]
1998	$400,000	$250,000 [2]
1999	$250,000	$250,000
2000	---	$250,000
2001	---	$250,000
Total	$1,650,000	$1,601,000

[1] Actual expenses

[2] Estimated actual expenses

APPLICATIONS OF STUDY RESULTS

Flow recommendations in the Anadromous Fish Restoration Plan are based on the assumptions that spawning habitat increases with flow from 1,200 to 2,500 cfs for the American River, and from 3,250 to 5,500 cfs for the Sacramento River. The results of the above studies will show whether the above assumptions are valid, and if spawning habitat continues to increase above 2,500 cfs for the American River and above 5,500 cfs for the Sacramento River. The results of the Sacramento River winter-run chinook salmon spawning modeling will shed light on tradeoffs, associated with reduced summer flows, between potential positive effects of higher habitat area versus meeting temperature requirements further upstream. Overall, the results of the above studies may support a revised seasonal allocation of flow releases from Shasta and Folsom Dams, with perhaps higher flows in the fall and lower flows in the summer.

Results of the spawning habitat modeling can be used to determine the extent of redd dewatering associated with various flow reductions. This information could be used along with the results of the proposed stranding and spawning & rearing habitat modeling analyses to develop a revised Sacramento River regulation program.

The Anadromous Fish Restoration Plan identifies supplementation of Merced River flows as a high priority action. The results of the proposed Merced River investigations will provide guidance on the degree of supplementation needed to enhance fall-run chinook spawning in the Merced River.

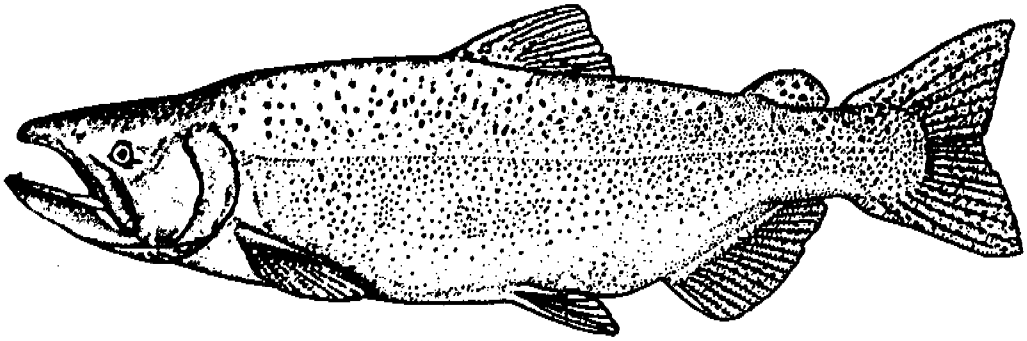
The Anadromous Fish Restoration Plan identifies completing an Instream Flow Incremental Methodology study on the Bear River as a high priority activity. The results of our proposed study would be used to implement two other high-priority activities identified in the Anadromous Fish Restoration Plan for the Bear River: 1) improve flows for all life stages of chinook salmon and steelhead; and 2) provide adequate water temperatures for all life-stages of chinook salmon and steelhead.

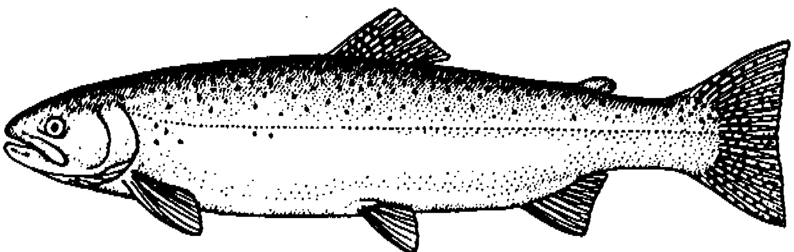
The results of our proposed studies on Butte, Deer, Mill, Antelope and Cow Creek would be valuable to Program staff in making decisions on how much water to buy for fisheries releases to these streams.

APPENDIX B

EXISTING INSTREAM FLOW INFORMATION FOR ANADROMOUS SALMONIDS ON UPPER SACRAMENTO RIVER TRIBUTARIES

EXISTING INSTREAM FLOW INFORMATION FOR ANADROMOUS SALMONIDS ON UPPER SACRAMENTO RIVER TRIBUTARIES





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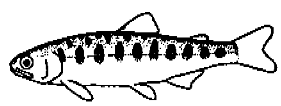

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Prepared by staff of
The Energy, Power and Instream Flow Assessments Branch

ANADROMOUS DOUBLING PLAN INSTREAM FLOW INVESTIGATIONS EXISTING INSTREAM FLOW INFORMATION FOR ANADROMOUS SALMONIDS ON UPPER SACRAMENTO RIVER TRIBUTARIES

PREFACE

The following is a report for the U. S. Fish and Wildlife Service's Anadromous Doubling Plan Instream Flow Investigations, a 7-year effort which began in February, 1995. Title 34, Section 3406(b)(1)(B) of the Central Valley Project Improvement Act, P.L. 102-575, requires the Secretary of the Interior to determine instream flow needs for anadromous fish for all Central Valley Project controlled streams and rivers, based on recommendations of the U. S. Fish and Wildlife Service after consultation with the California Department of Fish and Game (CDFG). The purpose of these investigations is to provide scientific information to the U. S. Fish and Wildlife Service Central Valley Anadromous Fish Restoration Program to be used to develop such recommendations for Central Valley rivers.

To those who are interested, comments and information regarding this report are welcomed. Written comments or information can be submitted to:

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INTRODUCTION

The Instream Flow Assessment Branch prepared an initial Draft Study Proposal dated October 31, 1994 which proposed instream flow investigations on six Central Valley streams (Sacramento River, Cow Creek, Antelope Creek, Deer Creek, Butte Creek and Bear River). After meetings with managers and staff of the Central Valley Anadromous Fish Restoration Program (Program) and the California Department of Fish and Game (CDFG), Streamflow and Habitat Evaluation Program, the Instream Flow Assessment Branch's proposal was amended in a final Draft Study Proposal, dated December 15, 1994, to revise the scope of study to five streams (Sacramento, American, Merced and Bear Rivers and Butte Creek) over a five-year period (from October 1994 through September 1999). The above five streams were chosen because they historically had healthy anadromous fisheries; the declining status of their anadromous resources is largely due to insufficient streamflows; available information on which reliable instream flow recommendations can be made is incomplete; and because Program managers consider them a high priority.

In a Revised Study Proposal, dated February 26, 1998, the Instream Flow Assessment Branch proposed to extend the period of the Anadromous Doubling Plan Instream Flow Investigations for an additional two years, through September 2001. This proposal included as a task preparation of a report reviewing the available instream flow studies and identifying what additional instream flow studies were needed for the following streams: 1) Deer Creek; 2) Mill Creek; 3) Butte Creek; 4) Bear River; 5) Cow Creek; and 6) Antelope Creek. Based on this report, the Instream Flow Assessment Branch will consult with Program and other resource agency staff in August 1998 to prioritize work for FY 99 through FY 2001 for the following potential work: 1) habitat modeling of chinook salmon spawning in the Sacramento River between Battle Creek and Deer Creek; 2) habitat modeling of chinook salmon rearing in the Sacramento River between Battle Creek and Deer Creek, including juvenile stranding; 3) development of a water temperature model and modeling of steelhead spawning and rearing habitat in the Bear River; 4) modeling of Sacramento River white sturgeon spawning habitat; 5) modeling of post-January-1997-flood Merced River chinook salmon habitat; 6) habitat and temperature modeling of instream flow requirements for anadromous salmonids in Cow Creek and its tributaries; 7) modeling of upstream and downstream passage of anadromous salmonids and temperature modeling in Antelope Creek; 8) modeling of passage flows, water temperature and instream flows for fall-run chinook salmon rearing and spawning in Deer Creek; 9) modeling of passage flows, water temperature and instream flows for anadromous salmonid rearing and spawning in Butte Creek; and 10) modeling of passage flows, water temperature and instream flows for fall-run chinook salmon rearing and spawning in Mill Creek. Available time will limit the number of the above activities which could actually be accomplished during FY 99 to 2001. In developing this report, we searched for and reviewed instream flow studies performed for resource agencies, utilities (ie PG&E), and water agencies.

INSTREAM FLOW STUDIES QUALITY CONTROL CRITERIA

The current state of the art for physical habitat studies is using the PHABSIM (Physical Habitat Simulation) programs. The current accepted practice is to place transects to model spawning habitat in known spawning areas, while a mesohabitat mapping approach is used to place transects to model rearing habitat. For upstream passage evaluations, transects are placed at locations where passage obstructions would first occur as flows decrease. At least two transects should be placed in simple mesohabitat units (ie riffles and runs), while at least three to five transects should be placed in more complex mesohabitat units (ie pools and pocket waters). For transects located in areas with backwater effects (such as pools), an additional transect should be placed at the downstream hydraulic control. If more than 15% of the reach is composed of island complexes, transects should be placed in island complexes.

The first step in simulating physical habitat is to simulate water surface elevations (WSELs). Three programs in PHABSIM (*IFG4, WSP* and *MANSQ*) can be used to simulate water surface elevations. The proper use of *IFG4* requires at least three sets of water surface elevations for calibration. *IFG4,* the most versatile of these models, is considered to have worked well if the following standards are met: 1) the beta value (a measure of the change in channel roughness with changes in streamflow) is between 2.0 and 4.5; 2) the mean error in calculated versus given discharges is less than 10%; 3) there is no more than a 25% difference for any calculated versus given discharge; and 4) there is no more than a 0.1 foot difference between measured and simulated WSELs. The Stage of Zero Flow for a transect (used by *IFG4*) should be the greater of: 1) the lowest bed elevation of the transect; or 2) the lowest bed elevation of a downstream transect. For *MANSQ*, all but the first standard apply; in addition, the beta value parameter used by *MANSQ* should fall within the range of 0 to 0.5. The standards for *WSP* are: 1) there is no more than a 0.1 foot difference between measured and simulated WSELs; 2) the Manning's n value should fall within the range of 0.04 to 0.07; and 3) there should be a negative log-log relationship between the reach multiplier and flow. At all simulated flows, WSELs at upstream transects should be greater than at downstream transects (ie water should not be going uphill). Velocities are simulated using the *IFG4* program; the current recommended practice is to use only one velocity set collected at a high flow. The main parameter used to evaluate the quality of velocity simulations is the Velocity Adjustment Factor (VAF); VAFs typically increase monotonically with increasing flows and should fall within the range of 0.2 to 5.

WSELs should be measured to the nearest 0.01 feet, while depths and bed elevations should be measured to the nearest 0.1 feet (Bovee 1994). Velocities should be measured to the nearest 0.01 ft/s. For depths less than 2.5 feet, the velocity should be measured at 0.6 of the depth, while for depths greater than 2.5 feet but less than 4 feet, the velocity should be measured at 0.2 and 0.8 of the depth. For depths greater than 4 feet, the velocity should be measured at 0.2, 0.6 and 0.8 of the depth. Velocity should be measured for at least 20 seconds for velocities greater than 1.5 ft/s, and for at least 40 seconds for velocities less than 1.5 ft/s. There should be at least 20 verticals at a low flow, with at most 10% of the flow going through one cell. The highest flow at which WSELs are measured should be at least five times the lowest flow at which WSELs are measured. Flows for calibration should be obtained from gaging stations or from averaging flows calculated at transects that are good for stream gaging. Flows should be steady during measurements of velocities and WSELs.

Habitat suitability indices (HSI) are used to convert hydraulic and structural components (ie depth, velocity and substrate or cover) into habitat area. Three are three major types of HSI: 1) Type 1, developed based on best professional judgement; 2) Type 2, developed based on measurements of habitat use; and 3) Type 3, developed based on measurements of habitat use and availability. Type 1 criteria are questionable and Type 3 criteria are no longer recommended for use. Either Type 2 HSI should be developed on the subject stream, or transferability tests (Thomas and Bovee 1994) should be conducted to ensure that Type 1 or Type 2 HSI are transferable to the subject stream. For chinook spawning, a technique should be used to adjust depth habitat utilization curves for availability (Gard 1998). Chinook rearing curves should include cover and adjacent velocity. Flows should not be simulated greater than 2.5 times the velocity set flow or less than 0.4 times the velocity set flow.

The current state of the art for water temperature modeling is the SNTEMP model. The time step for SNTEMP should be at least the travel time at the lowest flow for which temperatures are to be simulated. For temperature predictions, the correlation coefficient should be at least 0.9, the mean and bias errors should be less than 0.5 °C , the probable error should be less than 1.5 °C, the maximum error should be less than 3.5 °C, and the pseudo-source distance should be positive.

COW CREEK

Instream flow information needed in the Cow Creek watershed include: 1) the relationship between instream flow and habitat availability for fall- and late fall-run chinook salmon spawning, rearing and upstream passage in Cow Creek and its tributaries (South Cow, Old Cow, and North Cow Creeks); 2) the relationship between instream flow and habitat availability for steelhead trout spawning, rearing and upstream passage in South Cow, Old Cow, and North Cow Creeks; and 3) the relationship between instream flows and water temperature in Cow Creek and its tributaries. No instream flow studies have been performed in the Cow Creek watershed to investigate the flow requirements for anadromous salmonids. PG&E owns and operates the Kilarc-Cow Creek Project (FERC License No. 606) in the Cow Creek watershed with two diversions, one on Old Cow and one on South Cow Creek. PG&E stated that a barrier limits anadromous fish to the lower part of Old Cow Creek well below Kilarc Diversion, while the South Cow Creek diversion incorporates a ladder and screen for anadromous fish (primarily steelhead). PG&E conducted instream flow studies using the Water's Methodology (a precursor to PHABSIM) on both diverted reaches, but the studies only looked at resident trout habitat (Curtis Steitz, PG&E, personal communication). Information from instream flow studies using the Water's Methodology can not be used to develop an adequate flow-habitat relationship.

ANTELOPE CREEK

Instream flow information needed on Antelope Creek include: 1) the flows necessary for adult and juvenile anadromous salmonid passage below the two major diversions at the canyon mouth; and 2) the relationship between instream flows and water temperatures between the diversions and the Sacramento River. No instream flow studies have been conducted on Antelope Creek.

DEER CREEK

Instream flow information needed on Deer Creek include: 1) the flows necessary for adult and juvenile spring-run chinook and steelhead passage; 2) the relationship between instream flow and fall-run chinook spawning, rearing and passage; and 3) the relationship between instream flows and water temperatures below the diversions on Deer Creek. Spawning and rearing habitats for spring-run chinook and steelhead are located above diversions in the valley floor and are reported to be relatively unaltered, while fall-run chinook salmon spawn below the diversions. CDFG initiated instream flow investigations on Deer Creek, but these efforts were discontinued due to problems with access; these studies did not progress far enough to determine the above needed instream flow information (Bill Snider, CDFG, personal communication). No other instream flow studies have been conducted on Deer Creek.

BUTTE CREEK

Instream flow information needed on Butte Creek include: 1) the relationship between instream flow and habitat availability for fall-run chinook salmon spawning and rearing between the upper two diversion dams where most of this population is known to reproduce; 2) the relationship between instream flow and habitat availability for for spring-run chinook salmon and steelhead in the reach between the upper-most diversion dam and the Centerville Head Dam; 3) the flows necessary for adult and juvenile passage between the diversion dams located on Butte Creek; and 4) the relationship between instream flows and water temperatures.

Spawning Habitat

PG&E conducted instream flow investigations on Butte Creek between Centerville Head Dam and Little Butte Creek (located approximately half-way inbetween Centerville Powerhouse and Parrot Phelan Dam) in 1982 as part of the FERC relicensing of the DeSabla-Centerville Project (FERC 803). Three transects were placed in each of eight sites (five between Centerville Head Dam and Centerville Powerhouse, and three between Centerville Powerhouse and Little Butte Creek). Sites were placed exclusively in likely spawning areas, as determined by the presence of suitable substrate for spawning. Velocities and WSELs were measured at two or three flows (Table 1). *IFG4* was used to simulate WSELs. All of the velocity sets were used to simulate velocities. The habitat suitability criteria used (Figure 1) were developed on other rivers and

Table 1
Butte Creek Calibration Flows (cfs)

Reach	Low Flow	Mid Flow	High Flow
Centerville Head Dam to Centerville Powerhouse	12.4	22.3	45.3 - 45.4
Centerville Powerhouse to Little Butte Creek	none	95	142.2 - 150

there was no transferability testing performed to ensure that the criteria would be transferable to Butte Creek. These curves appear to be the fall chinook spawning curves from Bovee (1978) with a slight modification of the depth curve. Habitat area was simulated from 5 to 100 cfs for the Centerville Head Dam to Centerville Powerhouse reach, and from 50 to 220 cfs for the Centerville Powerhouse to Little Butte Creek reach (Figure 2).

Since no report was prepared on this study, we are unable to assess the adequacy of transect placement or field data collection. Our review of the Tape 11 and Tape 12 outputs of the PHABSIM modeling disclosed some serious problems in the hydraulic calibration. Many of the beta values fell outside of the range of 2 to 4.5; one transect (Site 3, Transect 3) had a beta value of 15.3. There also appeared to be some problems with the stage of zero flow; for Site 1, the stage of zero flow values for Transects 2 and 3 were lower than the stage of zero flow at Transect 1; stage of zero flow values should either stay the same or increase going upstream. *MANSQ* and/or *WSP* should have been used to simulate WSELs for Sites 6, 7 and 8, since WSELs were only measured at two flows (insufficient for using *IFG4*). Only the highest-flow velocity set should have been used to simulate velocities - extrapolating above the highest-flow velocity set using multiple velocity sets can result in significant errors in velocity simulation. The *IFG4* input decks no longer exist, but could be recreated from the information in the Tape 11 and Tape 12 outputs. The HSI criteria used in this study were developed on other rivers with no transferability test performed. As a result, it is not known whether the HSI criteria used are transferable to Butte Creek. In addition, the steep decline in suitability with increasing depth was likely due largely to availability.

The minimum level of effort to develop an adequate habitat-flow relationship for chinook salmon spawning in Butte Creek would involve: 1) recreation of the *IFG4* input decks and a new hydraulic calibration; 2) collection of spring-run and/or fall-run chinook salmon habitat utilization data for development of site-specific HSI criteria; 3) modification of the depth criteria using the techniques of Gard (1998); and 4) simulation of habitat availability at a range of flows. However, additional habitat data collection might be necessary if a significant portion of fall-run chinook salmon spawn downstream of Little Butte Creek.

Figure 2
Butte Creek Chinook Salmon Spawning HSI Criteria

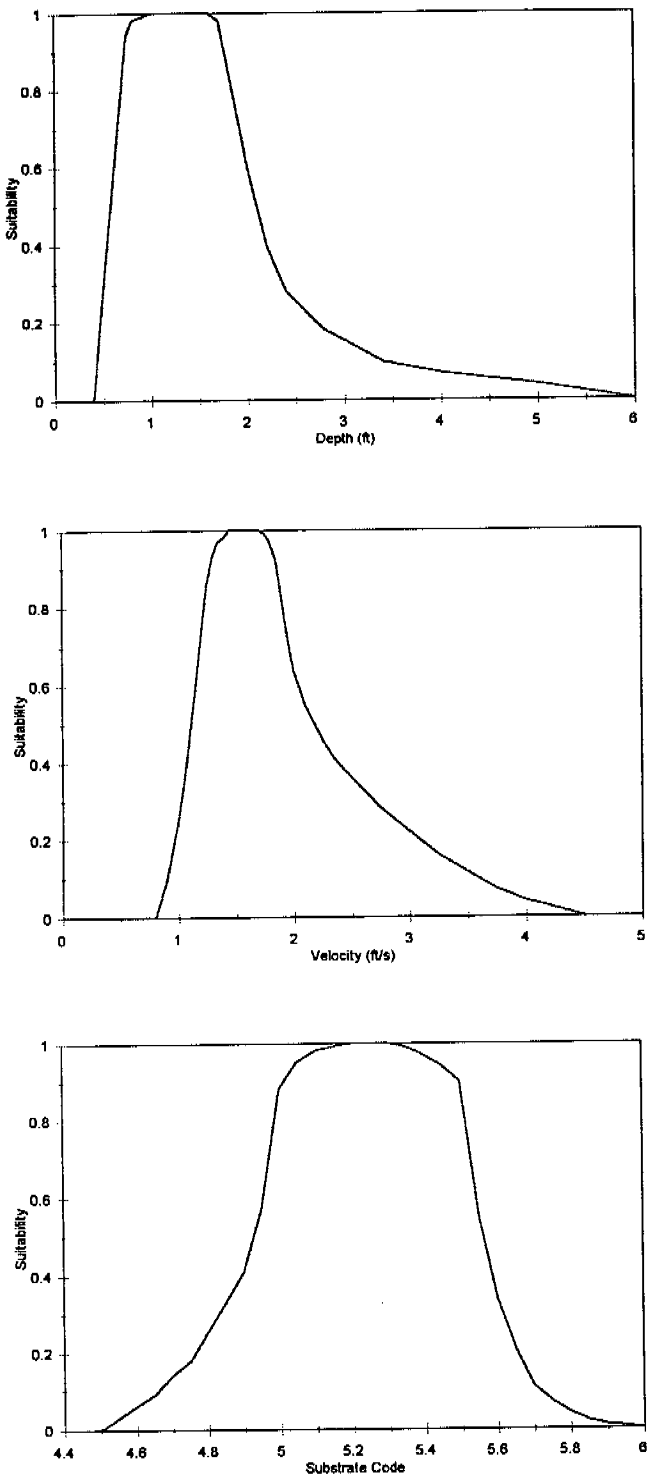
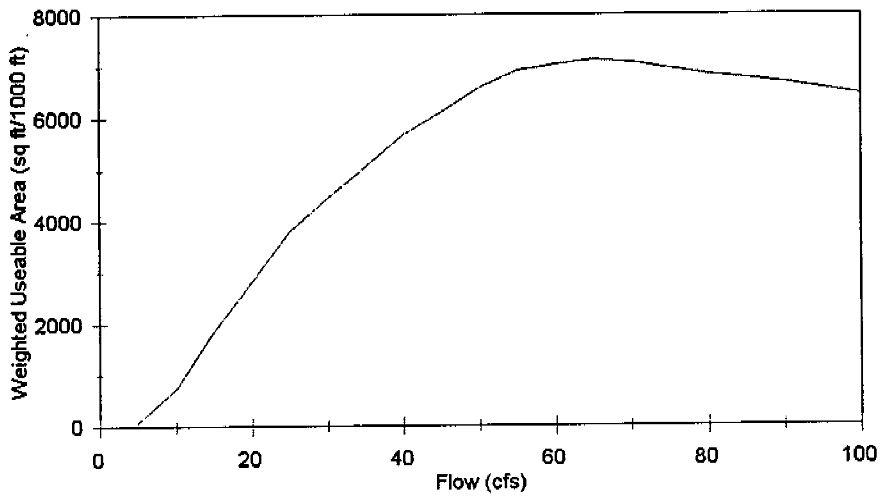
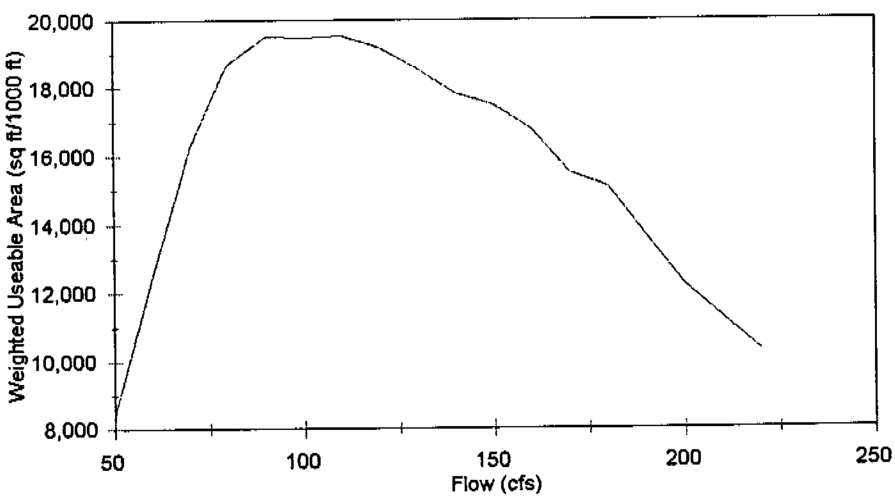


Figure 2
Butte Creek Chinook Salmon Spawning Habitat Area

Centerville Head Dam to Centerville Powerhouse



Centerville Powerhouse to Little Butte Creek



Water Temperature

An SNTEMP water temperature model was developed for Butte Creek from Centerville Head Dam to 1.5 miles upstream of Centerville Powerhouse as part of the FERC relicensing of the DeSabla-Centerville Project (Kimmerer and Carpenter 1989). Time of travel studies conducted as part of this study found that the time of travel through the study reach was 10 and 33 hours at 45 and 10 cfs, respectively. The model was developed using a daily time step. The model included two validation nodes, one at the bottom of the study reach and one approximately one mile upstream of the bottom of the study reach. The model was calibrated using data from 1986 and validated using data from 1987 (Table 2). The statistics in Table 2 are the combined values for the two validation nodes. Although Kimmerer and Carpenter (1989) state that the error terms from the model calibration and validation were unacceptably large, the statistics in Table 2 fall within the acceptable range of values, with the only slight exception being the maximum error for the validation run (ie 3.6 versus acceptable range of up to 3.5). Although the time step was less than the travel time at the lowest flow modeled, the results of the model are still acceptable. However, if the model were to be extended farther downstream, a larger time step (ie one week) would be necessary. The existing data could be averaged to create a one-week-time-step model.

Table 2
Butte Creek SNTEMP Model Statistics

Parameter	Calibration Run	Validation Run
Dates	5/8 - 9/17/86	5/6 - 10/31/87
Flow Range (cfs)	10 - 191	11 - 103
Initial Water Temperature Range (°C)	9.4 - 18.3	9.9 - 20.1
Air Temperature Range (°C)	11.4 - 27.0	13.3 - 28.7
Correlation Coefficient	0.98	0.95
Mean Error (°C)	0.02	-0.5
Probable Error (°C)	0.3	0.5
Maximum Error (°C)	2.4	-3.6
Bias Error (°C)	0.02	0.03

To develop an adequate relationship between flow and water temperature in Butte Creek, the above SNTEMP model would need to be converted to a one-week-time-step model and considerable additional field work would be required to extend the model further downstream.

Rearing Habitat and Upstream/Downstream Passage

No instream flow studies have been performed on Butte Creek to investigate the relationship between flow and rearing habitat, or to investigate minimum flows required for fish passage.

Data Integration

If the above SNTEMP and PHABSIM efforts were conducted, they would be combined to produce a relationship between streamflow and total habitat for chinook spawning.

BEAR RIVER

Instream flow information needed on Bear River include: 1) the relationship between instream flow and fall-run chinook salmon and steelhead trout spawning and rearing; and 2) the relationship between instream flows and water temperatures.

An IFIM study conducted for the proposed Garden Bar project (FERC No. 5222) examined the the relationship between streamflow and microhabitat availability for spawning and juvenile rearing for fall-run chinook salmon, and developed a relationship between water temperature and flow using the U.S. EPA QUAL2E water quality model (Holton Associates 1985, South Sutter Water District 1988). It appears from the project report (Holton Associates 1985) that a representative reach approach was taken for transect placement. Two study sites were chosen: 1) Gravel Company (with seven transects); and 2) Hudson Road (with nine transects). Holton Associates (1985) states that the Gravel Company site was selected because of its use by chinook salmon (life stage not identified) and would be treated as a critical reach for spawning, but was too wide to be representative of the lower Bear River, whereas the Hudson Road site was representative of the lower Bear River. Water surface elevations were measured at three or four flows, with velocity sets collected at the highest flow (Table 3). In general, there did not appear to be any errors in measurements of water surface elevations; the exceptions were two cases where WSELs were lower at an upstream transect than at a downstream transect, although they were only 0.01 feet lower. We were unable to determine the quality of any other aspects of transect placement or field data collection. However, we were able to check the quality of the hydraulic calibration. The *IFG4* program was used to simulate water surface elevations. In general, the hydraulic calibration met the standards identified at the beginning of this report. Exceptions included three transects with beta values exceeding 4.5 (with the highest being 5.1), two cases with water going uphill (resulting from the above-noted errors in measurement of water surface elevations), and three transects with VAFs less than 0.2 for low flows. In particular, one of the transects had VAFs less than 0.2 for flows of 15 to 100 cfs, with the highest VAF (at 450 cfs) being only 0.35, indicating that the velocity set at this transect substantially underestimated the actual flow. The report did not discuss how the values for the calibration flows were determined. The above-noted problems with beta values and water going uphill could be corrected by using *MANSQ* and *WSP* to simulate WSELs at these transects. The

Table 3
Bear River Calibration Flows (cfs)

Site	Low Flow	Mid Flow(s)	High Flow
Gravel Company	40.1	66.3	145
Hudson Road	35.05	64.38, 140.36	185.09

stage of zero flow values used would be correct if stage of zero flow elevations were surveyed in below the downstream-most transect and between transects; the report does not state if this was done.

Data was collected on the Bear River for juvenile chinook salmon rearing microhabitat use and availability. This data was used to modify juvenile rearing HSI curves from other rivers for use on the Bear River. The criteria used included velocity, depth and substrate, but did not include cover or adjacent velocity. Criteria used for chinook salmon spawning (Figure 3) appear to be the fall chinook spawning curves from Bovee (1978) with a modification of the substrate curve (apparantly to correspond with the substrate coding used for the transects). Since the spawning criteria used in this study were developed on other rivers with no transferability test performed, it is not known whether these criteria are transferable to the Bear River. In addition, the steep decline in suitability with increasing depth was likely due largely to availability.

Figure 4 presents the relationship between flows and weighted useable area for chinook salmon spawning using the criteria in Figure 3. Results are presented for both sites combined (all sixteen transects) and for only the Gravel Company site, since this was identified as a critical reach for spawning. Results from the Gravel Company site might be more comparable to the recommended current procedures to only place spawning transects in known spawning areas.

The minimum level of effort to develop an adequate habitat-flow relationship for chinook salmon spawning in the Bear River would involve: 1) collection of fall-run chinook salmon and steelhead habitat utilization data for development of site-specific HSI criteria; 2) modification of the depth criteria using the techniques of Gard (1998); 3) a site visit to the Gravel Company and Hudson Road sites to determine which of these sites are comparable to the hydraulic conditions present in areas used for spawning by fall-run chinook salmon and steelhead, to determine if any additional transects would be required; 4) simulation of habitat availability at a range of flows; 5) conversion of the QUAL2E data into an SNTEMP model to develop a temperature-flow relationship; and 6) combining the habitat availability and temperature modeling results to

Figure 3
Bear River Chinook Salmon Spawning HSI Criteria

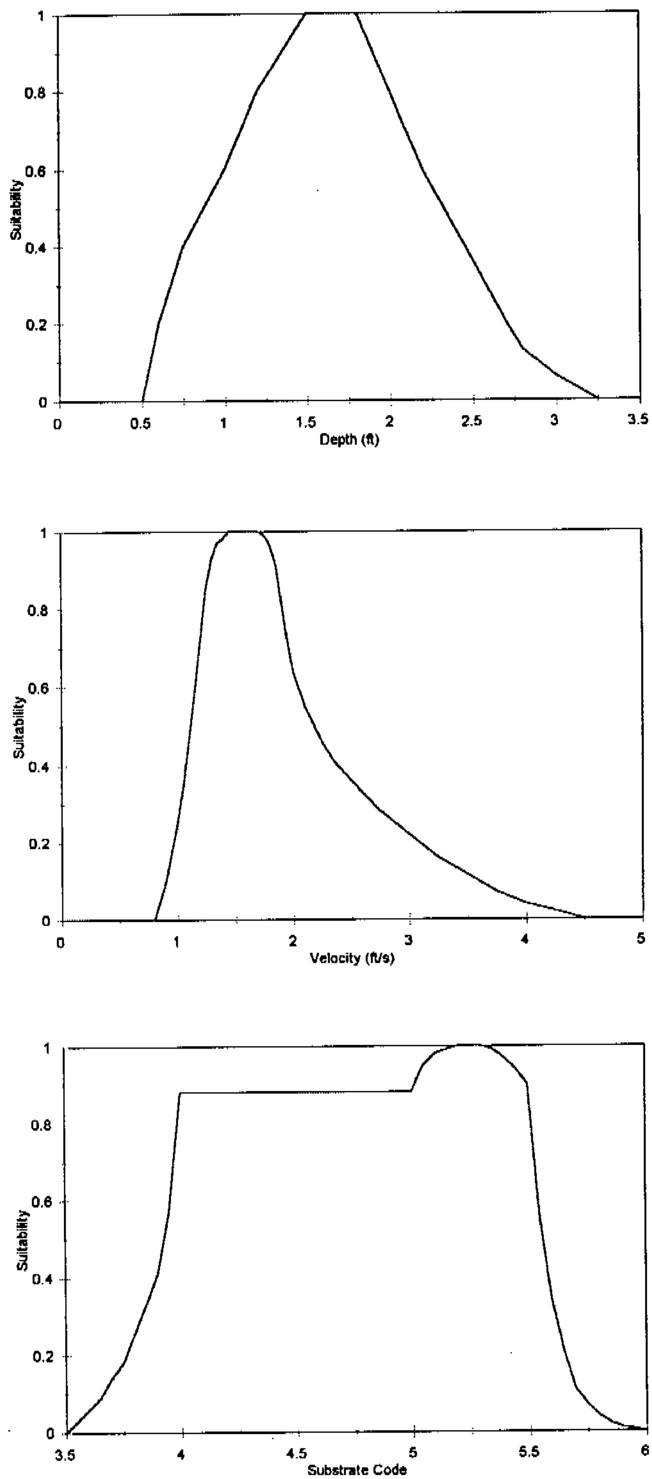
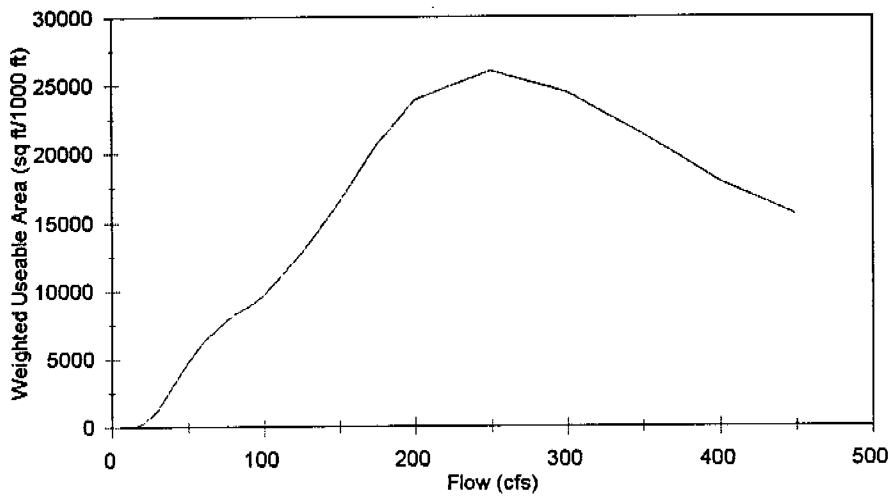
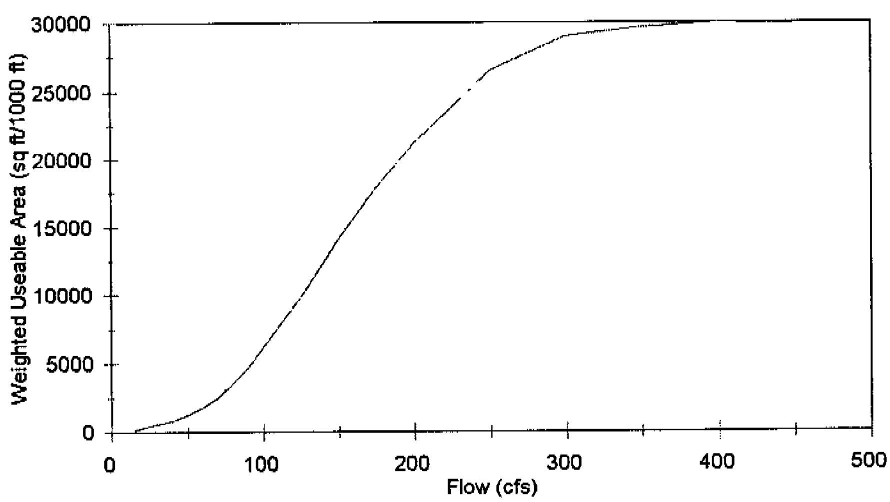


Figure 4
Bear River Chinook Salmon Spawning Habitat Area

All Transects



Gravel Company Site



develop a relationship between flow and total habitat area. Results of the Garden Bar IFIM studies could not be used to adequately assess the relationship between streamflow and juvenile chinook salmon and steelhead rearing habitat, since cover data was not collected for either criteria or transects. Accordingly, we would need a complete field data collection and modeling effort to assess the relationship between streamflow and juvenile chinook salmon and steelhead rearing habitat.

MILL CREEK

Instream flow information needed on Mill Creek include: 1) the flows necessary for adult and juvenile spring-run chinook and steelhead passage; 2) the relationship between instream flow and fall-run chinook spawning, rearing and passage; and 3) the relationship between instream flows and water temperatures below the diversions on Mill Creek. Spawning and rearing habitats for spring-run chinook and steelhead are located above diversions in the valley floor and are reported to be relatively unaltered, while fall-run chinook salmon spawn below the diversions.

Snider (1995) placed a total of eleven transects in five sites (three identified barriers and two other habitat areas) to examine flows needed for upstream passage of chinook salmon. Bed elevations, velocities and three sets of water surface elevations were measured at the transects. Results of PHABSIM modeling, if conducted, are not presented in the report. Snider (1995) concluded that without trenching, flows of over 300 cfs would be needed for upstream passage at one of the barriers, and that flows of somewhat less than 100 cfs would be required at a second barrier for upstream passage.

Alley (1996) placed two transects in each of three sites where passage obstructions would first occur as flows decreased. One of the three sites modeled by Alley (1996) was the same as one site examined by Snider (1995); Alley (1996) noted that there had been significant changes in the bed configuration of this site between the two data collection efforts as a result of high flows. WSELs were measured at two to five flows at each transect (Table 4), and for five of the six transects velocity sets were collected at the highest of these flows. At least 20 verticals were placed across each migration channel at the lowest simulated flow. For these five transects, *MANSQ* was used to simulate WSELs from 10 to 250 cfs. For transect T-3, WSELs at all simulated flows were determined by subtracting 0.6 feet from the WSEL at an upstream transect; 0.6 feet was the difference in WSEL between these two transects at the two calibration flows for transect T-3. The WSELs were used along with the bed elevations at each vertical on each transect to calculate the depths across the transects at each simulated flow. The hydraulic calibration appears adequate, since simulated WSELs at the calibration flows were within 0.1 feet of the measured WSELs.

Alley (1996) used the following criteria for upstream passage: 1) a minimum of 25% of the migration channel width was at least 0.7 feet deep; and 2) a continuous portion of the migration channel, at least 10% of the migration channel width, was at least 0.7 feet deep. The criteria used

Table 4
Mill Creek Calibration Flows (cfs)

Transect	Low Flow(s)	Mid Flow	High Flow(s)
T-1, T-2	14.5, 34.2	107.0	183.9, 252.7
T-3	15.0, 31.6	None	None
T-4	15.0, 31.6	111.3	190.8
T-5	14.0, 32.5	112.1	185.9, 362.2
T-6	14.0, 32.5	112.1	185.9

for downstream passage were: 1) a minimum of 25% of the migration channel width was at least 0.3 feet deep; 2) a continuous portion of the migration channel, at least 10% of the migration channel width, was at least 0.3 feet deep; and 3) at least 5 continuous feet of the channel was at least 0.3 feet deep. The percentages of channel width come from Thompson (1972). Thompson (1972) states that "the relationship between flow conditions on the transect and the relative ability of fish to pass has not been evaluated," indicating that the percentage criteria are Type I criteria. The depth portion of the criteria are a modification of Lauman (1976), who recommends 0.8 feet for upstream passage of chinook salmon and 0.2 feet for downstream passage of juvenile salmonids; these criteria also appear to be Type I criteria. Alley (1996) modified the depth criterion for adult passage based on an assumed average depth of adult chinook salmon, and that passage would be adequate if the stream depth was sufficient to submerge the adult fish; accordingly, this is also a Type I criterion. The depth criteria for juvenile passage was modified based on observations in other streams of steelhead smolt passage. In reviewing the literature, we were unable to discover any Type II passage criteria. Alley (1996) also presented results for adult passage with depth criteria of 0.8, 0.6 and 0.5 feet, and for juvenile passage with a depth criterion of 0.2 feet. Alley (1996) suggested that depths of 0.5-0.6 feet might be an appropriate compromise between water delivery and fish passage for dry years.

Alley (1996) recommended upstream passage flows of 157 cfs in normal and wet years (based on 0.7 foot criterion), 111 cfs in below normal and dry years (based on 0.6 foot criterion) and 74 cfs in critically dry years (based on 0.5 foot criterion). Alley (1996) recommended downstream passage flows of 27 cfs.

Two major issues need to be considered in evaluating the applicability of the available information on chinook salmon passage in Mill Creek, and thus whether additional studies are needed: 1) whether there have been significant changes to the channel of Mill Creek as a result of the January 1997 storms that would have changed the minimum flows needed for passage; and

2) whether the criteria used by Alley (1996) are transferable to Mill Creek. There are conflicting opinions among resource agency biologists whether there have been significant changes to Mill Creek that would affect minimum passage flows as a result of the January 1997 storms (Bill Snider and Paul Ward, CDFG, personal communications). While there is a biological basis for the depth portion of the criteria, fish use observations need to be collected to determine the numerical value of the depth criterion, especially since the minimum flows are sensitive to the depth criterion. In addition, the numerical value for the percentage of channel width appears to be an arbitrary value; it is unknown how sensitive the minimum flow would be to this portion of the passage criteria.

Since transferability tests have not been performed to determine if the existing Type I criteria would be tranferable to Mill Creek, we would recommend that site-specific passage criteria be developed on Mill Creek. One possible way to develop the criteria would be to monitor fish passage at transect locations as flows are increasing, recording the WSEL at which fish start to pass; repeated observations at multiple locations and multiple periods of increasing flows could be combined to develop criteria. The criteria could also include variable suitability - for example, upstream passage criteria might range from a suitability of 0 (no passage) for less than 5% of the width at less than 0.5 feet to a suitability of 1 (optimal) for 10% of the continuous width at 0.8 feet. This would allow an incremental assessment of fish passage versus flow, so that tradeoffs could be evaluated.

No instream flow studies have been conducted to determine the relationship between Mill Creek flows and fall-run chinook salmon spawning and rearing, or the relationship between Mill Creek flows and water temperatures below the diversions on Mill Creek.

Battle Creek

Payne and Associates (1995) conducted instream flow studies on five reaches in the Battle Creek watershed to assess the relationship between instream flows and chinook salmon spawning and rearing. A mesohabitat mapping approach was used primarily for transect placement. However, transects were also placed in known chinook salmon spawning areas in three reaches (Mainstem Battle Creek [4 transects], Eagle Canyon Subreach [2 transects] and South Fork Battle Creek [3 transects]. It appears that the field data collection and hydraulic calibration met the standards identified above. Site-specific Type II juvenile chinook salmon rearing criteria were developed by Payne and Associates on Battle Creek. Spawning criteria used were spring-run chinook spawning criteria from Bovee (1978) and Type II fall-run chinook salmon spawning criteria developed in Battle Creek by Vogel (1982). Transferability tests have not been performed to determine if the Bovee (1978) curves would be transferable to Battle Creek. In addition, the rapid decrease in suitability with depth for both curve sets is likely due largely to availability. In developing the criteria, Vogel (1982) measured velocities at 0.5 feet off of the streambed, rather than measuring mean column velocity. Velocity at 0.5 feet off of the bottom would be expected to be less than mean column velocity for depths greater than 1.2 feet. As a result, Vogel's criteria would be inappropriate to use with PHABSIM, which uses mean column velocity. The flow-weighted-usable-area relationships using only the spawning transects were different from those using all transects for two of the three reaches; for the mainstem reach, the spawning transects resulting in weighted usable area peaking at 100 cfs, versus at 80 cfs for all transects. For the Eagle Canyon Subreach, the spawning transects showed a bimodal distribution of weighted usable area, with the highest peak at 180 cfs, versus a unimodal curve with a peak at 40 cfs for all transects. A limiting-factors analysis indicates that spawning, rather than juvenile rearing, would be the limiting life stage for chinook salmon habitat area in Battle Creek (Mike Ward, Terraqua Environmental Consulting, personal communication).

The minimum level of effort to develop an adequate habitat-flow relationship for chinook salmon spawning in Battle Creek would involve: 1) identifying which transects in the other reaches would be most similar to the spawning transects in the mainstem, Eagle Canyon and South Fork reaches; and 2) simulation of habitat availability at a range of flows for the spawning transects with chinook spawning curves which have a modification of the depth criteria using the techniques of Gard (1998) - one possible curve set would be the criteria we developed on the Merced River. Alternatively, site-specific criteria could be developed on Battle Creek for both spring and fall-run spawning, with a modification of the depth criteria using the techniques of Gard (1998).

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